

**Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, DC 20554**

In the Matter of)	
)	
Use of Spectrum Bands Above 24 GHz For)	GN Docket No. 14-177
Mobile Radio Services)	
)	
Establishing a More Flexible Framework to)	IB Docket No. 15-256
Facilitate Satellite Operations in the 27.5-28.35)	
GHz and 37.5-40 GHz Bands)	
)	
Petition for Rulemaking of the Fixed Wireless)	RM-11664
Communications Coalition to Create Service)	
Rules for the 42-43.5 GHz Band)	
)	
Amendment of Parts 1, 22, 24, 27, 74, 80, 90,)	WT Docket No. 10-112
95, and 101 To Establish Uniform License)	
Renewal, Discontinuance of Operation, and)	
Geographic Partitioning and Spectrum)	
Disaggregation Rules and Policies for Certain)	
Wireless Radio Services)	
)	IB Docket No. 97-95
Allocation and Designation of Spectrum for)	
Fixed-Satellite Services in the 37.5-38.5 GHz,)	
40.5-41.5 GHz and 48.2-50.2 GHz Frequency)	
Bands; Allocation of Spectrum to Upgrade)	
Fixed and Mobile Allocations in the 40.5-42.5)	
GHz Frequency Band; Allocation of Spectrum)	
in the 46.9-47.0 GHz Frequency Band for)	
Wireless Services; and Allocation of Spectrum)	
in the 37.0-38.0 GHz and 40.0-40.5 GHz for)	
Government Operations)	

COMMENTS OF STRAIGHT PATH COMMUNICATIONS INC.

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TABLE OF CONTENTS

I.	INTRODUCTION AND SUMMARY	2
II.	THE COMMISSION CORRECTLY IDENTIFIES THE APPROPRIATE BANDS FOR INITIAL MOBILE MMWAVE DEVELOPMENT.....	4
III.	RULES FOR THE LICENSED MMWAVE BANDS SHOULD REFLECT THAT 5G IS A WIDE-AREA MOBILE BROADBAND TECHNOLOGY, <i>NOT</i> A SMALL CELL OR HOT SPOT TECHNOLOGY	8
	A. 5G Can Be Used to Cover Small Areas, But Its Key Value Is Wide-Area Broadband Mobility.	8
	B. The Commission Should Issue New Exclusive Geographic Area Licenses Assigning Mobile Rights to Existing 28 GHz and 39 GHz Licensees.	14
	C. The License Area for the 28 GHz and 39 GHz Bands Should Be the Same or Similar as the Geographic Service Areas for 4G.	17
	D. The FCC Should Adopt a Band Plan That Facilitates 5G Mobile Services.....	22
IV.	THE COMMISSION SHOULD BE CAUTIOUS WHEN PERMITTING MOBILE AND SATELLITE SERVICES IN THE SAME BAND	27
	A. Mobile Broadband Technology Is Capable of Providing 5G Services Far More Effectively Than Fixed Satellite Services.....	27
	B. There Are Technological Problems and Limitations of FSS Operations in the Same Bands as Mobile Services, and Challenging Interference Coordination in the 39 GHz Band.	30
	C. Operation of FSS Gateway Earth Stations in the 28 GHz Band Does Not Present the Same Interference Risks.	37
V.	LICENSING, OPERATIONS, AND PERFORMANCE RULES	38
VI.	TECHNICAL RULES	40
	A. Flexible Duplexing Rules.....	40
	B. Transmission Power Limits and Antenna Height	40
	C. Limits on Terrestrial Emissions.	43
	D. Equipment Authorization.....	44
VII.	CONCLUSION	45
	Appendix A.....	A-1
	Appendix B.....	B-1

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GHz for Government Operations)	

COMMENTS OF STRAIGHT PATH COMMUNICATIONS INC.

Straight Path Communications Inc. (“Straight Path”) submits these comments in response to the Notice of Proposed Rulemaking (“*NPRM*”) issued by the Federal Communications Commission (“Commission” or “FCC”) in the above-referenced proceedings.^{1/} The *NPRM*

^{1/} See *Use of Spectrum Bands Above 24 GHz For Mobile Radio Services, et al.*, Notice of Proposed Rulemaking, 30 FCC Rcd. 11878 (2015) (“*NPRM*”); see also Notice of Inquiry, 29 FCC Rcd. 13020 (2014) (“*NOI*”). The *NPRM* established January 26, 2016 as the deadline for the submission of

identifies specific spectrum bands above 24 GHz—known as the millimeter wave (“mmWave”) bands—that are suitable for mobile service, and seeks comment on proposed service rules that would authorize mobile and other operations in those bands.^{2/} Straight Path applauds the Commission’s efforts to develop a regulatory framework to promote flexible use of the mmWave bands and facilitate deployment of Fifth Generation (“5G”) mobile services and urges the Commission to adopt rules promptly to establish the regulatory certainty that will drive deployment of mmWave mobile technologies.

I. INTRODUCTION AND SUMMARY

Straight Path supports the Commission’s findings that mmWave spectrum is a critical component of 5G development. Now is the right time for the FCC to develop rules governing mobility use of mmWave bands.

First, the Commission correctly identifies the appropriate bands for initial mobile mmWave deployment, and it strikes the right balance between different licensing models. We support the Commission’s proposal to use the 28 GHz and 39 GHz bands for licensed use—granting mobile rights to existing licensees. The Commission’s proposed hybrid licensing approach in the 37 GHz band merits further consideration in this proceeding. We also support the proposal to reserve the 64-71 GHz band for unlicensed use.

Second, the Commission’s rules for Upper Microwave Flexible Use Service should reflect that licensed mmWave 5G is a wide-area mobile broadband technology, *not* a small cell or hot spot technology. Therefore, the rules governing license area, term, technical parameters, and exclusive use should mirror those applicable to today’s 4G services, which have a proven

comments. However, because the Commission was closed on that day, these comments are timely filed on the next business day. *See* 47 C.F.R. §§ 1.4(e)(1),(j).

^{2/} *NPRM* at ¶¶ 1–3.

track record of success. We agree with the FCC’s proposal to grant exclusive geographic area licenses assigning mobile rights to existing 28 GHz and 39 GHz licensees. We oppose, however, the FCC’s proposal to license mobile services on a county-wide basis in the 28 GHz and 39 GHz bands. Small geographic service areas will present administrative and technical challenges for mmWave operations and discourage investment in 5G services and technologies. We encourage the FCC to grant mobile licenses in the 28 GHz and 39 GHz bands based on the existing geographic licensing schemes for those bands.

Third, the Commission should adopt rules that reflect its stated criteria for the selection of bands in which to implement 5G—namely, the availability of large spectrum blocks.^{3/} In particular, the Commission should depart from its proposal and implement a band plan at 39 GHz that better facilitates 5G mobile services, and also adopt a pre-auction spectrum exchange program.^{4/}

Fourth, while Straight Path commends the Commission for seeking to adopt rules that would permit mmWave bands to be used flexibly, it remains concerned about the use of satellite services—particularly downlink services—in bands co-channel with mmWave mobile use. Fixed Satellite Service (“FSS”) downlink operations in the same bands as mmWave mobile services will create challenging interference scenarios.

^{3/} See *id.* at ¶¶ 20–23 (identifying criteria for evaluating suitability of mmWave bands for mobile use, including a “focus on bands with at least 500 MHz blocks of contiguous spectrum.”). Given the “nascent state of mmWave mobile technology,” the Commission believes its “initial efforts should be focused on the band where the most spectrum is potentially available.” *Id.* at ¶ 20.

^{4/} See Letter from Russell H. Fox, counsel for Straight Path Communications Inc. to Marlene H. Dortch, Secretary, FCC, GN Docket No. 14-177, RM-11664, at 2 (filed Nov. 23, 2015) (“Straight Path Nov. 2015 Ex Parte Notice”); Letter from Russell H. Fox and Stephen J. Wang, counsel for Straight Path Communications Inc. to Marlene H. Dortch, Secretary, FCC, GN Docket No. 14-177, at 4–5 (filed Sept. 11, 2015) (“Straight Path Sept. 2015 Ex Parte Notice”).

Fifth, we propose that the Commission’s licensing, operating, and performance rules permit existing licensees to make substantial service demonstrations prior to the end of their current license terms in order to promote rapid deployment of 5G technologies.

Sixth, the FCC should not impose security requirements, which are inconsistent with its general practice against mandating the use of particular technologies or device features and risk stifling investment and further developments in 5G mobile technologies and services.

Finally, we applaud the FCC’s proposed technical rules and believe that they will advance the Commission’s goal of encouraging flexible use and fostering innovation and investment in 5G technologies and services.

II. THE COMMISSION CORRECTLY IDENTIFIES THE APPROPRIATE BANDS FOR INITIAL MOBILE MMWAVE DEVELOPMENT

The Commission identifies four mmWave spectrum bands for which it proposes to adopt rules that will facilitate mobile wireless operations.^{5/} These are the correct bands on which the Commission should focus for now. As Straight Path explained in a recent white paper,^{6/} the prime spectrum for geographically licensed 5G mobile services lies between 24 GHz and 57 GHz. The International Telecommunications Union agrees and has identified spectrum in this range that will be studied for mobile services by the United States and other countries as a result of the 2015 World Radiocommunication Conference (“WRC-15”).^{7/} From a technology

^{5/} See, e.g., *NPRM* at ¶ 4 (proposing rules for the 28 GHz, 39 GHz, 37 GHz, and 64-71 GHz bands).

^{6/} White Paper, *A Straight Path Towards 5G*, Straight Path Communications Inc. (Sept. 16, 2015), available at http://spathinc.com/spci/downloads/whitepapers/White_Paper_-_A_Straight_Path_Towards_5G.pdf.

^{7/} The Agenda Item for the next WRC conference in 2019 (“WRC-19”) identifies 11 bands between 24.25 GHz and 86 GHz as candidates to be studied by the International Telecommunication Union (“ITU”) for mobile services. See *World Radiocommunication Conference 2015 (WRC-15), Presentation to the FCC Open Meeting*, Report at 6–7 (Int’l Bur. Dec. 17, 2015), available at http://transition.fcc.gov/Daily_Releases/Daily_Business/2015/db1217/DOC-336915A1.pdf. Three of the four bands under consideration by the Commission in this proceeding are among those 11 bands, meaning that the bands the Commission has identified are likely to be internationally harmonized for mobile

standpoint, the bands below 57 GHz have distinct advantages over bands above 57 GHz for wide-area mobile services due to the achievable output power and efficiency of solid state power amplifiers.

Licensed Operations in the 28 GHz, 39 GHz, and 37 GHz Bands. The Commission proposes to designate the 28 GHz, 39 GHz, and 37 GHz bands for licensed mobile use.^{8/} Straight Path agrees with this proposal. Because an exclusive licensing framework already exists in the 28 GHz and 39 GHz bands, the addition of mobile services in these bands will be relatively straightforward. Although technology advancement may eventually overcome the limitation of solid state electronics in frequencies above 57 GHz, the FCC’s proposal to make the 28 GHz, 39 GHz, and 37 GHz bands available for licensed mobile use is a good first step in accomplishing the quantum leap of mobile communication from sub-3 GHz to mmWave bands.

Hybrid Authorizations in the 37 GHz Band. Straight Path commends the Commission for seeking information about the viability of a shared licensing model.^{9/} Spectrum scarcity requires the Commission to think creatively about how to make additional capacity available to meet expanding wireless needs. While the Commission must dedicate sufficient spectrum for exclusively licensed spectrum to ensure that licensees drive investment and innovation, it should also explore other approaches when appropriate. The 37 GHz band may not be ideal for exclusive licensed services because of the existing complex spectrum landscape in that band,^{10/}

wireless use. The 28 GHz band and part of the 64-71 GHz band (from 64-66 GHz)—which the Commission proposes for mobile 5G use in the United States—were not among WRC’s candidates to be studied by ITU for WRC-19. *Id.* According to the Commission, however, eight countries joined with the U.S. in stating that they will pursue studies in the 28 GHz band. *Id.*

^{8/} See *NPRM* at ¶¶ 30, 42, 51, 92. The 37 GHz band would be licensed, but with unlicensed indoor use.

^{9/} See *id.* at ¶¶ 99–104.

^{10/} See *id.* at ¶¶ 47–50.

and it therefore may be an appropriate candidate for an experimental approach. Should the Commission find, however, that it is in the public interest to provide additional exclusive mmWave spectrum to support 5G mobile broadband, then it may wish to consider Verizon's proposal^{11/} to combine the 37 GHz and 39 GHz bands into a single, contiguous three gigahertz band subject to the same service rules as exclusive Economic Area ("EA") licenses. In that case, the 64–71 GHz band, or a portion of it, may be considered as a testbed for hybrid licensing or other type of sharing mechanisms.

Unlicensed Use in the 64–71 GHz Band. The Commission proposes to make the 64–71 GHz band available for unlicensed use.^{12/} As Chairman Wheeler has remarked, “an effective spectrum strategy requires an all-of-the-above approach” that includes making spectrum available for both licensed and unlicensed use, and for both exclusive use and shared use.^{13/} So, it is appropriate for the Commission to dedicate spectrum for unlicensed use in the mmWave bands. The 64–71 GHz band is immediately adjacent to the 57–64 GHz band that is already allocated for unlicensed use, making a significant amount of spectrum available for high-capacity, short-range Wi-Fi applications. This will increase the economies of scale and scope for unlicensed operations in the mmWave bands and further improve the commercial viability of the technology. As noted above, hybrid licenses can also be considered for this band in the event that the Commission implements an exclusive licensing scheme for the 37 GHz band.

^{11/} See Letter from Charla Rath, Vice President, Wireless Policy Development, Verizon to Marlene H. Dortch, Secretary, FCC, GN Docket No. 14-177, at 1 (filed Jan. 14, 2016).

^{12/} *NPRM* at ¶ 58.

^{13/} See *NOI*, Statement of Chairman Tom Wheeler.

Other Bands. The *NPRM* considers, but rejects, other mmWave spectrum bands for 5G development.^{14/} Straight Path appreciates others’ desires to make as much mmWave band spectrum available as possible in order to establish U.S. leadership in 5G technologies.^{15/} It is concerned, however, that progress will be unnecessarily delayed if the scope of this initial effort becomes too broad. The industry still faces challenges to develop technologies, products, and successful business models to provide mobile services, even in the limited number of bands identified in the *NPRM*. In the meantime, the Commission’s proposal strikes the right balance to meet the growing demand of spectrum while focusing on the bands that can likely generate more immediate success.^{16/} As Chairman Wheeler observed, the *NPRM* proposes to authorize 3,850 megahertz of spectrum for licensed mobile use, which is “six times as much spectrum as ever proposed in any previous Commission proceeding,” and to “double the amount of high-band unlicensed spectrum to 20 times as much as all unlicensed Wi-Fi spectrum in lower bands.”^{17/}

^{14/} See *NPRM* at Section IV.A.3, ¶¶ 60–91 (electing not to propose service rules at this time for the following bands: 24.25–24.45 GHz and 25.05–25.25 GHz; 29.1–29.25 GHz and 31–31.3 GHz; 31.8–33 GHz; 42–42.5 GHz; 71–76 GHz and 81–86 GHz; and above 86 GHz).

^{15/} See *id.*, Statement of Commissioner Ajit Pai Approving in Part, Dissenting in Part, Statement of Commissioner Michael O’Rielly Approving in Part, Dissenting in Part; see also, e.g., Comments of FiberTower Spectrum Holdings, LLC, GN Docket No. 14-177, *et al.*, at 16 (filed Jan. 15, 2015) (supporting mobile use in the 24 GHz band); Comments of Nokia (d/b/a Nokia Solutions and Networks US LLC), GN Docket No. 14-177, at 28–29 (filed Jan. 15, 2015) (same); Letter from Robert Kubik, Ph.D., Director, Public Policy, Engineering and Technology, Samsung Electronics America, Inc. and Samsung Research America to Marlene H. Dortch, Secretary, FCC, GN Docket No. 14-177, at 2 (filed Aug. 28, 2015) (supporting mobile use in the 31.8–33.4 GHz band); Comments of Akbar Sayeed, GN Docket No. 14-177, *et al.*, at 9 (filed Dec. 16, 2014) (supporting mobile use in the 71–76 GHz and 81–86 GHz bands).

^{16/} See *NPRM* at ¶ 60 (“Given the early state of the development of technologies for mobile mmW band, and the complex sharing issues raised in these bands, we believe the best approach is to initially focus our efforts on the strongest candidate bands . . . which we believe are better positioned for more immediate use in the marketplace.”).

^{17/} *Oversight of the Federal Communications Commission: Hearing Before the Subcomm. on Commc’ns & Tech. of the H. Comm. on Energy & Commerce*, 114th Cong. 2 (Nov. 17, 2015) (Statement of Tom Wheeler, Chairman, FCC), available at https://apps.fcc.gov/edocs_public/attachmatch/DOC-336448A1.pdf.

As technology further progresses and the industry gains confidence in the commercial viability of mobile services in the mmWave bands, then the FCC should consider making more spectrum available to meet increased traffic demand in the future.

III. RULES FOR THE LICENSED MMWAVE BANDS SHOULD REFLECT THAT 5G IS A WIDE-AREA MOBILE BROADBAND TECHNOLOGY, *NOT* A SMALL CELL OR HOT SPOT TECHNOLOGY

A. 5G Can Be Used to Cover Small Areas, But Its Key Value Is Wide-Area Broadband Mobility

i. mmWave Spectrum Can Deliver Gbps Mobility

As noted below, many of the Commission’s proposals related to licensing of mmWave spectrum presume that it will be used exclusively for small cell or hot spot coverage.^{18/} However, these presumptions are not accurate. Instead, the mmWave spectrum is best used to provide Gigabit per second (“Gbps”) mobility with wide-area coverage.^{19/} Like its 3G and 4G technological predecessors, 5G should be a wide-area mobility solution. The strongest value proposition for mmWave 5G is as a wide-area Gbps mobile broadband technology, particularly when compared to other alternatives such as sub-6 GHz cellular systems (which carries prohibitively high per megahertz spectrum costs) or Wi-Fi hot spots (which requires prohibitively high deployment density).

^{18/} See, e.g., *NPRM* at ¶¶ 100 (proposing service rules for the 37 GHz band that account for “the inherent short-range characteristics of millimeter wave spectrum”), 202 (proposing a smaller coverage area requirement for mmWave bands because the “unique characteristics [of frequencies above 24 GHz] are likely to cause prospective licensees in these bands to be interested in serving relatively small geographic areas (e.g., urban areas), at least in the short-to-medium term”), 212–13 (proposing a county-based performance milestone “because of the relatively small coverage area of a site operating on mmW spectrum, deploying a wide-area network may not be ideal,” and anticipating that “initial deployments in these bands will take place in highly localized areas where there is demand for the speed and other characteristics these systems will provide”), 310 (proposing emission limits for Part 15 operations in the 64–71 GHz band).

^{19/} A mobile broadband connection delivering a typical data transfer speed of one Gbps in a majority of the service areas, and a minimum speed of 100 Mbps in most of the service areas.

Straight Path does not dismiss the use of mmWave 5G for small cells and hot spots, especially in urban areas where there is already good sub-6 GHz coverage. In those areas, operators may initially want to use mmWave 5G as a gap-filler where demand exceeds capacity. As mobile broadband demand continues to increase, however, it is unlikely that the limited spectrum available in the bands below 6 GHz will be able to satisfy that demand. As an alternative, mmWave 5G will be best able to provide Gbps broadband connectivity in wide-area mobility environments.

- ii. *Because mmWave 5G Will Be a Wide-Area Mobile Service, Large Service Areas are Appropriate.*

In order for 5G to be a successful wide-area mobility technology, we envision that the footprint of typical 5G cells will need to be at least two orders of magnitude larger than Wi-Fi hot spots. In other words, for the same coverage area that needs a few hundred Wi-Fi access points, a single 5G cell should suffice. This positioning will clearly distinguish 5G and Wi-Fi and allow each to flourish on their strongest value proposition, respectively. As our link budget analysis shows, these levels of coverage for 5G cells are attainable, even with the circuit technologies today.

For example, the link budget analysis for New York City is shown in the attached Appendix A, at Table 3.^{20/} In that case, we used a path loss formula of:

$$PL = 64.3 + 34\log_{10}d + 0.006d + PL_{other}$$

The link budget analysis for University of Texas at Austin campus is shown in Appendix A, Table 4.^{21/} In that case, we used a path loss formula of:

$$PL = 64.3 + 23\log_{10}d + 0.006d + PL_{other}$$

^{20/} See Appendix A, “Link Budget Analysis of 5G systems at 39 GHz in New York City, University of Texas Campus, and Rural Areas,” at Table 3.

^{21/} See *id.* at Table 4.

The link budget analysis for rural areas is shown in Appendix A, Table 5.^{22/} In that case, we used a path loss formula of:

$$PL = 64.3 + 20\log_{10}d + 0.006d + PL_{other}$$

The path loss formulae for New York City and University of Texas at Austin campus are based on comprehensive channel measurement at 28 GHz and 39 GHz.^{23/} The path loss formula for rural areas is based on free space propagation with additional loss factor. To make our analysis conservative, we add an additional 6 dB per kilometer to account for rain loss. In addition, we add another term PL_{other} to account for other losses due to penetration or blocking. The value of PL_{other} is assumed to be 10 dB for outdoor-to-outdoor deployments and 30 dB for outdoor-to-indoor deployments. For outdoor-to-outdoor deployments (both base stations and mobile stations are outdoor), this term accounts for loss due to human blocking and/or penetration of car windows.^{24/} For outdoor-to-indoor deployments (the base station is outside while the mobile station is indoor), this term accounts for penetration loss of the buildings.

iii. *mmWave Will Not be Limited to Indoor Deployments.*

There have been numerous studies on building penetration of mmWaves. For example, an NTIA report found that the penetration loss of 28.8 GHz depends on the building type, and the average penetration loss for different buildings can range from 12 dB to 35 dB.^{25/} The report

^{22/} See *id.* at Table 5.

^{23/} George R. MacCartney Jr. et al., *Millimeter-Wave Omnidirectional Path Loss Data for Small Cell 5G Channel Modeling*, IEEE Access (Sept. 18, 2015), available at <http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=7181638>.

^{24/} Although the human body block in close proximity at a certain spatial direction may exceed 10 dB, it is generally unlikely for a human body to block waves from all scatters. Therefore, we believe 10 dB is a good approximation to account for such penetration losses.

^{25/} NTIA Report 94-306, *Building Penetration Loss Measurements at 900 MHz, 11.4 GHz, and 28.8 GHz*, Nat'l Telecomm. & Info. Admin., U.S. Dep't of Commerce (May 1994), available at http://www.its.bldrdoc.gov/publications/download/94-306_ocr.pdf.

also found that the penetration loss can be more than 50 dB for certain locations in concrete buildings with multiple walls between the transmitter and receiver. Although it is possible (and economical) to achieve good indoor coverage in most cases, it is not realistic to achieve 100% indoor coverage with mmWave frequencies and outside-in deployments only (as is the case with 3G/4G in sub-6 GHz). This is not a major disadvantage of mmWave 5G, however, as 5G will be able to achieve good coverage for the majority of indoor locations, and other systems (indoor Wi-Fi, indoor hot spots, sub-6 GHz outside-in deployments, etc.) can be used in the few locations deep inside a few buildings with thick concrete walls where mmWave 5G does not provide good outside-in coverage.

The achievable inter-site distance (“ISD”) with 160 dB link budget is summarized in Table 1 below.^{26/} Generally, the range matches well with the Urban Micro (ISD = 200 meters), Urban Macro (ISD = 500 meters), and Rural Macro (ISD = 1732 meters).^{27/} This analysis confirms that mmWave 5G can generally achieve range similar to 4G LTE systems, and that large geographic license areas such as EAs and Basic Trading Areas (“BTAs”) are appropriate.

Table 1. *Achievable Inter-Site Distance (ISD) for mmWave 5G (28 GHz & 39 GHz)*

Achievable ISD (meters)	Outdoor-to-Outdoor (O2O)	Outdoor-to-Indoor (O2I)
NYC (28 GHz)	500 m	150 m
UT Austin Campus (39 GHz)	3100 m	900 m
Rural Area	4800 m	1700 m

iv. *5G Operations in the mmWave Bands Can Provide Reliable Coverage to Both Rural and Urban Areas.*

mmWave 5G can be successfully deployed in rural, as well as urban or suburban areas. As shown in the link budget analysis above, mmWave 5G cells will have radii ranging between

^{26/} The detailed link budget analyses are provided in Appendix A.

^{27/} Report ITU-R M.2135, *Guidelines for evaluation of radio interface technologies for IMT-Advanced*, Int’l Telecomm. Union (Nov. 2008), available at <http://www.itu.int/publ/R-REP-M.2135-2008/en>.

100 meters and one kilometer in *urban* areas. The path loss in suburban and rural areas will likely be much more favorable, resulting in larger cell radii. In rural areas where there is no frequent heavy rain fall or heavy foliage, the propagation of mmWave largely follows a free space path loss formula. 5G can achieve a cell radius well beyond one kilometer and can be economically viable for areas with low population density. Most of the U.S. land mass falls under ITU rain regions A–M, which experience rainfall intensity less than 22 mm/hr more than 99.9% of the time.^{28/} For 5G communication at 39 GHz, 22 mm/hr translates into approximately 6 dB/km rain loss. In rural areas where line of sight or near line of sight can often be established, a 5G system with 160 dB link budget can achieve ISD of 4.8 kilometers (approximately 20 square kilometer area coverage per cell) while still achieving 100 Mbps data rate.

It is not only technologically feasible, but also economically viable to implement 5G mmWave Gbps mobile broadband on a wide-area basis. As an example, assume there is an annual Average Revenue Per User of \$500, and annualized capital and operational expenditures of \$25k per cell. An operator would need to average 50 subscribers per cell under this scenario to break even. Assuming 25% market penetration, an operator would need 200 *potential* subscribers within each cell to break even, which translates into a population density of 10 people/km² for a cell with 20 km² coverage. Fortunately, based on U.S. Census in 2010, more than 98.6% of the U.S. population lives in counties with a population density of more than 10 people/km² (as displayed in Figure 1, below), which means that mmWave 5G can be economically viable in serving almost all of the U.S. population.

^{28/} Recommendation ITU-R PN.837-1, *Characteristics of Precipitation for Propagation Modelling*, Int'l Telecomm. Union (Aug. 1994), available at https://www.itu.int/dms_pubrec/itu-r/rec/p/R-REC-P.837-1-199408-S!!PDF-E.pdf. A pictorial representation of ITU rain regions in the United States is also available at <http://www.e-band.com/index.php?id=86>.

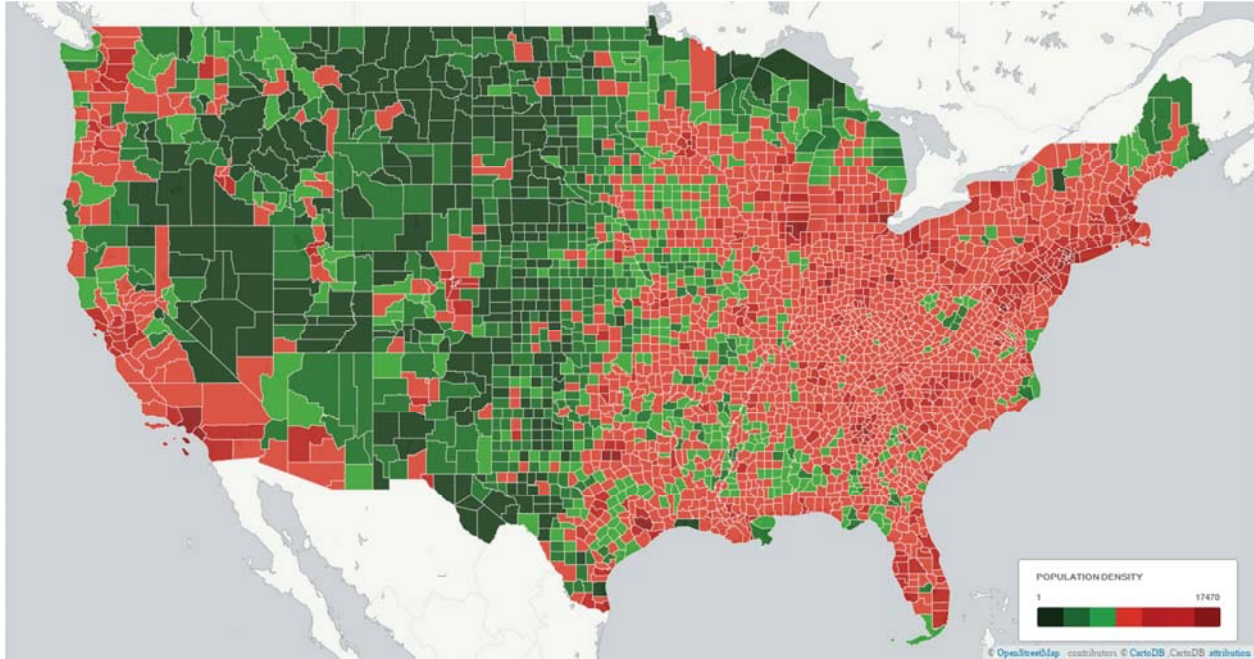


Figure 1. U.S. population density by county^{29/}

Even in counties with population density less than 10 people/ km², it is likely that majority of the population lives in a few small towns with each well served by a single 5G base station with a coverage area of 20 km².

Based on the foregoing, the Commission should adopt flexible licensing and performance rules that recognize the capability and key value of licensed mmWave 5G mobility as a wide-area technology that can provide reliable coverage to the majority of the U.S. population, both indoors and outdoors, and in both urban and rural areas. Rules that restrict deployment of mmWave mobile broadband to small cells and hot spots will unnecessarily limit the utility of the spectrum, jeopardize its commercial viability, and discourage investment and innovation in this important new technology.

^{29/} Counties with population density more than 10 people/km² are shown in different shades of red and counties with population density less than 10 people/km² are shown in different shades of green.

B. The Commission Should Issue New Exclusive Geographic Area Licenses Assigning Mobile Rights to Existing 28 GHz and 39 GHz Licensees.

i. *The Commission Should Grant Mobile Operating Rights to Incumbent Licensees.*

Straight Path supports the Commission’s proposal to grant mobile operating rights to existing 28 GHz and 39 GHz licensees for areas in which they currently hold licenses.^{30/} The Commission believes that this proposal will “alleviate . . . concerns about compatibility between fixed and mobile uses because a single licensee will be able to coordinate fixed and mobile operations while avoiding interference.”^{31/} Straight Path agrees that the Commission’s proposal would minimize transaction costs, promote expedited deployment of expanded services in the bands, and reduce the potential for harmful interference between fixed and mobile uses.^{32/}

ii. *The Commission Should not Issue Overlay Licenses in the 28 GHz and 39 GHz Bands.*

While acknowledging that its “principal proposal is to directly assign flexible use rights to existing licensees in lieu of establishing an overlay right” in areas with existing licensees,^{33/} the Commission requests comment on an alternative proposal to establish an overlay right for new licensees in the 28 GHz and 39 GHz bands, subject to noninterference with the incumbent licensees.^{34/} Straight Path strongly opposes the issuance of overlay licenses. There should be only one entity authorized to provide flexible mmWave services using specified channels in a geographic area.

Most importantly, there is no practical way to mitigate interference between a fixed service network with an overlaying mobile service network when the two networks are

^{30/} *NPRM* at ¶¶ 95–96.

^{31/} *Id.* at ¶¶ 41, 43.

^{32/} *Id.* at ¶¶ 92–98.

^{33/} *Id.* at ¶ 97.

^{34/} *Id.* at ¶ 93.

controlled by different entities. Straight Path has invested in developing a point-to-multipoint system at 39 GHz and expects to bring that system to the U.S. market in 2016. It is also developing its own 5G transceiver at 39 GHz, which it expects to initially deploy for point-to-multipoint fixed service. These systems generally have a coverage area comparable to a 5G mobile system, and each site has similar characteristics of a 5G cell. Overlaying another 5G cell on top of it would be analogous to having two mobile operators building two separate mobile networks on the same frequency in the same area. This is not technologically feasible. It is challenging even for a single licensee to coordinate fixed and mobile operations in the same geographic area. The addition of a second licensee operating on the same channel in the same area would make that coordination impossible.

The Commission's "relevant experience in the application of overlay rights in other bands"^{35/} is not applicable here. The Commission notes that it previously established overlay rights in the 39 GHz band when it overlaid EA licenses on the existing Rectangular Service Areas ("RSA") licenses, and that it has "combined overlay licensing with mechanisms to relocate incumbent users in the PCS, AWS-1, and AWS-3 bands."^{36/} Neither of these examples is relevant in this instance, however.

In the case of the 39 GHz band, the Commission decided that "the incumbent will retain the exclusive right to use [the overlap] channels within its rectangular service area," and "the holder of the BTA authorization thus will be required to design its system to protect against harmful interference to the incumbent by complying with the Commission's interference

^{35/} *Id.* at ¶ 97.

^{36/} *Id.* (citing *Amendment of the Commission's Rules Regarding the 37.0-38.6 GHz and 38.6-40.0 GHz Bands*, ET Docket No. 95-183, Report and Order and Second Notice of Proposed Rule Making, 12 FCC Rcd. 18600, 18637 ¶ 79 (1997) ("39 GHz R&O")).

protection standards.”^{37/} In effect, the incumbents were granted exclusive rights in their RSAs, which would not be the case here. The Commission also did not issue true “overlay licenses” in the PCS, AWS-1, and AWS-3 bands. Instead, it provided for the relocation of the incumbent point-to-point licensees from the bands. The Commission cannot replicate this process in the 28 GHz or 39 GHz bands where the incumbent licensees hold geographic area licenses and have developed technologies and business models based on those area licenses.

iii. *Competitive Bidding Should Be Used to Issue Licenses in Areas Where There Is No Existing Licensee, not for the Assignment of Overlay Rights.*

Straight Path agrees with the Commission’s proposal to use competitive bidding to assign licenses in areas where there is currently no active licensee.^{38/} It disagrees, however, with the purported “benefits” of auctioning overlay rights, which the Commission asserts would “assign these rights to the user that values the set of rights most highly, whether it be an incumbent licensee or a new potential user.”^{39/} Incumbents have already paid for the right to use the spectrum—with the reasonable expectation that the Commission may allow mobile service use in the future. Existing licensees recognized that at the time of auction for the 28 GHz and 39 GHz bands, and the Commission saw no reason why mobile service could not ultimately be allowed.^{40/} Accordingly, incumbent licensees have already valued the spectrum for its potential use. It would be inequitable to require incumbent licensees to re-acquire rights they reasonably believed they already had.

^{37/} 39 GHz R&O at 18637 ¶ 79.

^{38/} See NPRM at ¶ 93.

^{39/} See *id.* at ¶ 97.

^{40/} See 39 GHz R&O at 18603, 18612–14, ¶¶ 1, 18, 23 (permitting implementation of mobile operations in the 39 GHz band).

The Commission also cites as a benefit of overlay licenses that “the use of an auction, rather than a direct grant of additional rights to existing licensees, ensures that a portion of the value associated with these additional rights will accrue to the United States Treasury.”^{41/} The Communications Act of 1934, as amended (the “Act”), prohibits the Commission, however, from making the generation of auction proceeds the principal consideration in issuing authorizations.^{42/} Instead, the Commission should principally follow the other mandates in the Act, including ensuring the most efficient use of spectrum.^{43/} The economic benefits to the mobile industry and to the Nation that would result from issuing authorizations to incumbent licensees and auctioning the remainder far outweigh the speculative consideration of proceeds that may be generated by an overlay auction. Moreover, designing an overlay licensing scheme in the 39 GHz band—in addition to its technological challenges—will likely drive down the value of the spectrum and thus proceeds from auction. An overlay scheme would introduce economic uncertainty and would be unattractive for mobile operators to invest and build out 5G networks. Worse, it would jeopardize U.S. leadership in 5G mobility and deprive the public of the significant economic and social benefits that could have been derived from 5G technologies and services.

C. The License Area for the 28 GHz and 39 GHz Bands Should Be the Same or Similar as the Geographic Service Areas for 4G.

i. County-Based License Areas Are Not Suitable for mmWave 5G Operations.

As explained in Section III.A, above, 5G systems in the 28 GHz and 39 GHz bands can achieve similar coverage as 3G/4G cellular systems with similar deployment density. 5G

^{41/} NPRM at ¶ 97.

^{42/} See 47 U.S.C. § 309(j)(7)(a) (in making a decision to assign a band of frequencies, “the Commission may not base a finding of public interest, convenience, and necessity on the expectation of Federal revenues from the use of a system of competitive bidding”).

^{43/} See, e.g., 47 U.S.C. §§ 151; 309(j)(3)(D).

mmWave technology is capable of providing reliable service to wide geographic areas, not just small cells or Wi-Fi hot spots. The Commission should therefore adopt a geographic area licensing scheme for those bands that is similar to its existing approach for 3G/4G systems. Because the 39 GHz band is already licensed by EAs and the 28 GHz band is already licensed by BTAs, the Commission should retain those licensing schemes.

In contrast, under the Commission's proposal in the *NPRM*, there would be 3,143 licenses in the 28 GHz band and 44,002 licenses in the 39 GHz band.^{44/} This large number of licenses will increase administrative burdens on both the Commission and the licensees. Just as an example, the Commission would require licensees to demonstrate satisfaction of performance requirements on a per-license basis.^{45/} That would require the Commission to assess over 47,000 such demonstrations for the two bands, a daunting, resource-intensive administrative task.

County-based licenses will also produce inefficient spectrum use. Smaller geographic area licenses will increase the number of borders between licensees along which co-channel interference must be coordinated, increasing the complexity of network operation and potentially reducing the utilization of spectrum as the deployment density and power may need to be reduced to avoid interference to neighboring licensees. Straight Path recognizes that licensees can accumulate county-based licenses to approximate geographic service areas like EAs or BTAs. But that comes only with significantly increased administrative complexities, transaction costs, and business uncertainty. In contrast, the benefits of county-based licenses are entirely

^{44/} As noted below, this overwhelming number of licenses is created because the Commission proposes to issue 14 authorizations in each county. Straight Path suggests that the Commission reduce the number of licenses issued in each geographic area, which itself would ameliorate some administrative burdens and inefficiencies.

^{45/} See *NPRM* at ¶¶ 199–200 (proposing to license service areas by county and to measure performance requirements on a county basis).

unclear and do not appear to be based on an appreciation of the wide-area capabilities of licensed mmWave systems.

ii. *The Record Contains Little to no Support for County-Based Licenses.*

There is little, if any, support in the record for licensing the 28 GHz and 39 GHz bands on a county basis. In contrast, the Commission acknowledges that “six commenters supported licenses areas that are consistent with the current regime at 28 GHz and 39 GHz.”^{46/}

In particular, as NYU WIRELESS suggests, “traditional licensing using small areas such as MSAs, RSAs, or BTAs,” *not* county-based licenses, would be appropriate.^{47/} On balance, the record in the proceeding does not justify the Commission’s finding that counties would be an appropriate base geographic area unit for licenses in the mmWave bands. Conversely, the Commission notes that characteristics of millimeter wave spectrum must be taken into account in determining “both the geographic scope of licenses and performance requirements.”^{48/} As discussed in detail in Section III.A, above, a county-based licensing scheme is inconsistent with the characteristics mmWave 5G as a wide-area mobile broadband technology.

iii. *County-Based Licenses Will Not Necessarily Provide Flexibility for Targeted Deployments.*

The Commission also asserts that smaller geographic service areas could provide licensees with additional flexibility to target their deployments to those areas where they need the capacity.^{49/} Straight Path disagrees. As noted above, where there is a need for 4G service now, there will be a need for 5G service in the future. These areas cover most of the population

^{46/} *Id.* at ¶ 108.

^{47/} Comments of NYU WIRELESS, GN Docket No. 14-177, *et al.*, at 53 (filed Jan. 13, 2015).

^{48/} *NPRM* at ¶ 109 (citing Comments of the Consumer Electronics Ass’n, GN Docket No. 14-177, *et al.*, at 13 (filed Jan. 15, 2015)).

^{49/} *See id.* at ¶ 111.

in this country. The value of wide-area coverage and general availability of 5G services is an inherent part of the core value of mobile broadband. Limiting 5G services solely to hot spots available only to a small portion of the population would significantly diminish the value of licensed 5G. In order for 5G to deliver significant economic value and benefits, the geographic service areas for 5G services should be the same or similar as those for 4G services.

iv. *The NPRM Is Incorrect that mmWave Does Not Propagate Well Over Long Distances and Is Only Deployable in Urban or Suburban Areas.*

The Commission asserts that spectrum in the 28 GHz and 39 GHz bands “do[es] not propagate well over long distances.”^{50/} As discussed in Section III.A, above, this is inaccurate. In fact, FSS operations in the Ku and Ka bands facilitate communication between ground stations and geostationary satellites that are 36,000 kilometers apart. Even in terrestrial services, point-to-point and point-to-multipoint links on the order of several kilometers are commonplace in these bands today. In comparison, the cell radii of 3G and 4G services in bands below 3 GHz are often on the order of only a few hundred meters to several kilometers. As noted above, our link budget analyses^{51/} show a set of 5G system configurations that can achieve similar cell radii as typical 3G/4G systems. And these configurations are already achievable with the device capabilities in these bands today. In fact, many characteristics of mmWave frequencies—such as small wavelength, high gain antenna arrays in small form factors, and the higher directionality of spatial channels—have made it possible for innovative technologies to even better enable wide-area Gbps mobility in these bands.

^{50/} *Id.*

^{51/} *See* Appendix A.

v. *Smaller License Areas Will Not Reduce the Likelihood of Warehousing*

The Commission states that “smaller license areas reduce the potential for warehousing spectrum” and that “licensees will be more likely to acquire and hold only the licenses they need to meet their customers’ demand.”^{52/} This is a shortsighted view of spectrum utilization that ignores the long-term needs and value of large infrastructure projects like a nationwide 5G network. It takes years to build a next-generation mobile broadband network and decades to improve coverage and capacity based on changing demand. For the same reason that many mobile operators, infrastructure vendors, and chip vendors supported exclusive licensing of 5G mmWave spectrum, mobile operators also need certainty that spectrum will be available as mmWave 5G networks are rolled out over multiple years. Conversely, the uncertainty of the continued availability of spectrum in these bands (both in geographic areas and in time) will significantly discourage mobile operators from investing in 5G. If the Commission intends to only allow mobile operators to hold licenses that they can immediately deploy to meet current demand and significantly fragments the scope of those licenses by both geographic area and frequency, then the mmWave bands *will* be degenerated to a complementary solution as hot spots or gap fillers to 3G/4G, at best. This will significantly reduce the value of 5G and may jeopardize the economic viability of 5G in its entirety, and it will fundamentally deprive the Nation of a significantly improved broadband infrastructure with enormous economic and social benefits.

vi. *The Commission Has Other Tools Available to Facilitate Market Entry by Both Small and Large Carriers.*

^{52/} NPRM at ¶ 111.

The Commission states that “county based licenses could equally facilitate access by both small carriers and large carriers.”^{53/} As consolidation in the various segments of the communications industry continues, the need for county-based licenses available for small carriers is speculative at best. The Commission already has other tools, such as small business credits and secondary market transactions, to address those needs if they exist. If there is a need to satisfy the perceived demand of carriers serving limited geographic areas, then the Commission could consider meeting these needs in other bands, such as the 37 GHz band, while saving the 28 GHz and 39 GHz bands for the time-tested, exclusive licenses based on large geographic service areas (EAs or BTAs) that have been the foundation of this Nation’s successful mobile networks over the past three decades.

D. The FCC Should Adopt a Band Plan That Facilitates 5G Mobile Services.

The Commission proposes to keep the entire 28 GHz band as a single channel of 850 megahertz.^{54/} At 37 GHz, the Commission suggests possible band plans that “subdivide the band into three equal blocks of approximately 533 megahertz each” with the alternative to “have four blocks of 400 megahertz each.”^{55/} Straight Path agrees with these band plans that retain larger, contiguous blocks of spectrum for mmWave services for the reasons noted below.

The Commission departs from this approach, however, in its proposed plan for the 39 GHz band. Instead of reserving larger blocks of contiguous spectrum, the FCC instead proposes to maintain the current 14 channel pairs of 50 megahertz by 50 megahertz for the 39 GHz band.^{56/} This band plan does not align with current 5G technologies nor the Commission’s

^{53/} *Id.*

^{54/} *See id.* at ¶ 116.

^{55/} *See id.* at ¶ 117.

^{56/} *See id.*

criteria for bands targeted for 5G operations,^{57/} and it may hinder the deployment of 5G mobile services. Straight Path recommends that the Commission instead divide the 39 GHz band into three channels with 400 megahertz, 500 megahertz, and 500 megahertz each. If the Commission wishes to offer spectrum in smaller blocks, then it may wish to consider doing that in the 28 GHz band, which would otherwise be served only by a single licensee.

There are multiple reasons why the Commission should favor large unpaired spectrum blocks for 5G mmWave operations. *First*, 5G mobile services will be predominantly Time Division Duplex (“TDD”) based, not Frequency Division Duplex (“FDD”) systems which the current band plan favors. A primary reason FDD is not likely to be prevalent in the mmWave bands is frequency duplexer design. In FDD systems, the transmitter band and the receiver band are often only separated by a small percentage of the carrier frequency. For example, the GSM-850 MHz band has uplink-downlink separation of 45 megahertz for a carrier frequency around 850 MHz, and the GSM-1900 MHz band has uplink-downlink separation of 80 megahertz for a carrier frequency around 1900 MHz. The use of FDD in these frequencies is possible due to the ability to suppress leakage from the transmitter (“TX”) band to the receiver (“RX”) band in relative narrow guard band. This is achieved due to acoustic wave filters such as Surface Acoustic Wave, Bulk Acoustic Wave, and Film Bulk Acoustic Resonator filters. These filters have very sharp out-of-band emission suppression and are physically compact, so they can be easily integrated into mobile devices.

These technologies are not available in mmWave frequencies. At mmWave frequencies, the most viable frequency duplexers are cavity filters. These filters are often as big as an iPhone

^{57/} See *id.* at ¶ 20 (stating that the FCC “will focus on bands with at least 500 megahertz of contiguous spectrum” for mmWave use, and acknowledging that “virtually all commenters agree that it will be easier to accommodate mobile use in wider bands”).

and weigh hundreds of grams. FDD systems in these frequencies were previously feasible because the stations were big, and only a single transceiver chain (or at most two for diversity) was used per station. In mmWave 5G mobile systems, however, the number of transceiver chains increases significantly (e.g., 8 to 64 transceiver chains per station). In addition, one of the main applications—smart phones—will require multiple transceiver chains to fit in a smart phone. Straight Path is unaware of any FDD duplexer at these frequencies that can meet the performance, cost, and form factor requirements for the intended 5G mobile broadband operations in these bands. Conversely, TDD does not require such a frequency duplexer, and allows flexible adjustment of downlink-uplink ratio depending on traffic that can lead to more efficient utilization of spectrum. As most wireless traffic moves towards data, TDD is a more suitable technology to flexibly adjust the time slot allocation between downlink and uplink. Straight Path therefore strongly urges the Commission to proceed under the assumption that TDD will be the preferred mode of operation in these bands.

Second, 5G mobile broadband requires hundreds of megahertz of spectrum for each system. The 50 megahertz channelization will create impediments to the effective use of the spectrum. As noted above, the filters in the mmWave bands are not yet as good as the filters in the sub-6 GHz bands. Carrier aggregation, if at all possible, across non-contiguous channels in these frequencies will require expensive transceivers and front end devices. In addition, guard bands may need to be allocated between adjacent channels, leading to inefficient spectrum utilization if the channel size is too small.

We therefore recommend the 39 GHz band be divided into 400 megahertz or 500 megahertz channels. One possibility is to divide the band into three channels with 400 megahertz, 500 megahertz, and 500 megahertz for each channel as shown below in Table 2.^{58/}

Table 2. Proposed Plan for 39 GHz Band

Spectrum band	Block	Frequency (GHz)	Bandwidth (MHz)
39 GHz	A	38.6 – 39.0	400
	B	39.0 – 39.5	500
	C	39.5 – 40.0	500

The Commission should also consider adopting a pre-auction channel “swap” period during which licensees could exchange 50 megahertz EA-based spectrum blocks within an EA for blocks where there is no incumbent EA licensee. Such an exchange would allow licensees to consolidate current fragmented channels and secure authorizations for larger, contiguous spectrum blocks.^{59/} Straight Path recommends that in order to apply for a block where there is no EA license during the swap period, the applicant must have an authorization in an adjacent EA block. If mutually exclusive applications are submitted (because licensees on each “side” of a vacant block submitted applications), then the FCC would dismiss them after a 30-day period for applicants to modify applications to resolve mutual exclusivity.

If the Commission believes that it cannot dismiss mutually exclusive applications, then it should accept swap applications that are not mutually exclusive. Those applications would be where: (a) the applicant is already the EA licensee for both adjacent channels; or (b) the applicant is the EA licensee for one adjacent channel and there can be no other adjacent channel

^{58/} See Straight Path Sept. 2015 Ex Parte Notice.

^{59/} See *id.*; Straight Path Nov. 2015 Ex Parte Notice.

licensee. In both cases, the applicant could apply for all intervening blocks. In each instance, a swap would be for a 50 megahertz block where there is no EA licensee.^{60/}

The band plan for 39 GHz is pictured below as Figure 2. Under Straight Path’s plan to allow swaps that avoid mutual exclusivity, if a licensee held Blocks A1, B1, A4, B4, A7, B7, A9, B9, A10, and B10 in an EA (a total of ten 50 megahertz blocks) and there was no Block A2, A3, A5, A6, or A8 incumbent EA licensee in that EA, then it could swap its Blocks B1, B4, B7, B9, and B10 licenses for the Blocks A2, A3, A5, A6, and A8 licenses in the EA (giving it the same total of ten 50 megahertz blocks, but in a contiguous format) and create additional contiguous spectrum to auction. After the swap process, auction winners would be permitted to operate on any spectrum in the block they acquire except for spectrum licensed on an EA basis to an incumbent licensee. Where one or more incumbents are licensed for the entire block of spectrum in a geographic area, the Commission would not conduct an auction.

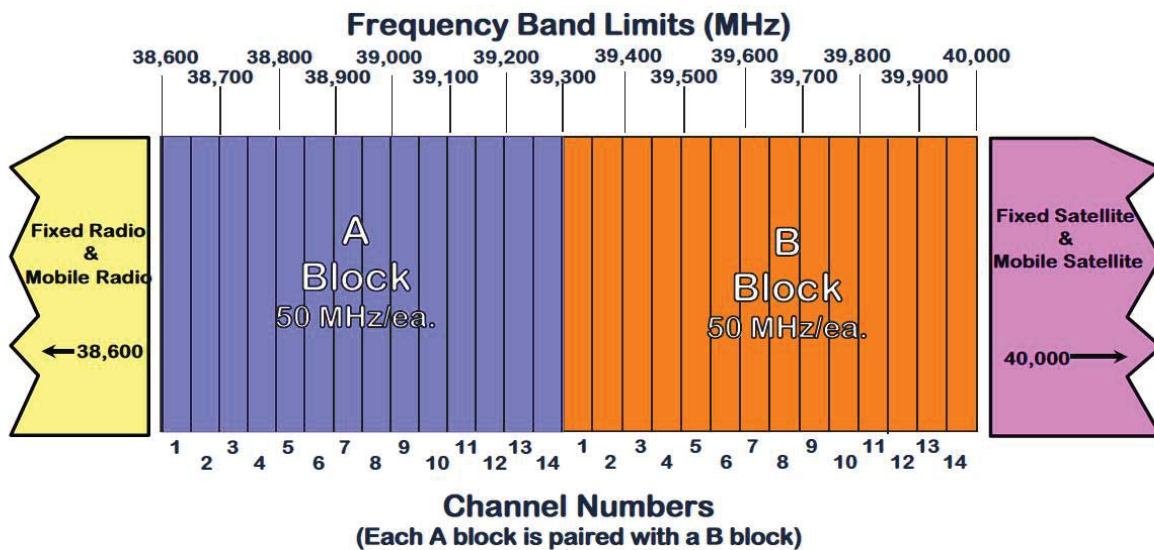


Figure 2. 39 GHz Band Plan

^{60/} Swaps would be permitted in instances where there is no EA license, but where rectangular service area (“RSA”) licensees exist. RSA licensees would be equally protected by incumbent licensees that swap as they would licensees of auctioned spectrum.

This proposed “swap” approach would allow incumbents to most efficiently utilize their spectrum for 5G mobile services. It would also enable the Commission to auction larger spectrum blocks, and provide the auction winners multiple hundred megahertz of contiguous spectrum for rapid deployment of 5G mobile services. Additionally, it would make the unallocated spectrum in the mmWave bands more valuable, and thus generate more proceeds for the government during the competitive bidding process.

IV. THE COMMISSION SHOULD BE CAUTIOUS WHEN PERMITTING MOBILE AND SATELLITE SERVICES IN THE SAME BAND

A. Mobile Broadband Technology Is Capable of Providing 5G Services Far More Effectively Than Fixed Satellite Services.

In the 28 GHz and 39 GHz bands, the Commission proposes “a traditional geographic area licensing scheme that is flexible to provide access and protection for fixed, mobile, and FSS uses.”^{61/} While Straight Path appreciates the Commission’s desire to introduce maximum flexibility, it should not do so at the cost of undermining the principal goal of this proceeding—to facilitate mobile use of the mmWave bands for 5G. It is significantly more spectrum efficient for terrestrial systems to provide those 5G services than it is for satellite systems to do so.

Take O3b as an example. According to O3b’s website, each of its satellites is equipped with 12 fully steerable Ka-band antennas (two beams for gateways, ten beams for remotes) that use 4.3 gigahertz of spectrum (2×216 megahertz per beam) with a throughput of up to 1.6 Gbps per beam (800 Mbps per direction), with a total capacity of 84 Gbps per eight satellite constellation (10.5 Gbps per satellite).^{62/} In other words, by using 4.3 gigahertz of spectrum, the

^{61/} NPRM at ¶ 92.

^{62/} See *Our Technology at a Glance*, O3b Networks, <http://www.o3bnetworks.com/technology/> (last visited Jan. 21, 2016) (“O3b Technology Webpage”); see also Steve Blumenthal, Chief Network Architect, O3b Networks, *Focus . . . Connecting The Other 3 Billion*, SatMagazine.com (July 2010), available at <http://www.satmagazine.com/story.php?number=281305822>.

O3b system provides 10.5 Gbps per satellite. Even assuming all 16 satellites can be successfully launched and operational (two of the 12 launched have already been placed in standby),^{63/} that would give 168 Gbps for the entire United States (with a population of 330 million). The spectral efficiency per MHz-POP would be 0.12 bps. In comparison, a 5G mobile broadband network with 500 megahertz of spectrum can be expected to achieve 10 Gbps per cell sites. With a reasonable assumption of 300,000 5G cell sites, the resulting spectral efficiency per MHz-POP is 18 kbps. In other words, for every megahertz of mmWave spectrum, FSS can provide 0.12 bps per person, while 5G can provide 18 kbps per person. Put simply, the spectrum utilization of 5G mobile broadband is about 150,000 times more efficient than satellite in this case.

Similar analysis can be performed for ViaSat-1, which provides 72 beams and 140 Gbps capacity for the United States and Canada.^{64/} User terminals transmit in frequency bands 28.35–29.1 GHz, 29.5–30.0 GHz and receive in frequency bands 18.3–19.3 GHz, 19.7–20.2 GHz. Gateway earth stations transmit in frequency bands 28.1–29.1 GHz, 29.5–30.0 GHz and receive in frequency bands 18.3–19.3 GHz, 19.7–20.2 GHz. In total, *three gigahertz* of spectrum is used for 140 Gbps for the entire United States, resulting in a spectral efficiency per MHz-pop of 0.14 bps, which is, again, about 130,000 times less efficient than what 5G can achieve.

^{63/} Peter B. de Selding, *Two O3b Satellites Taken Out of Service as a Precaution*, Space News (Sept. 11, 2014), available at <http://spacenews.com/41831world-satellite-business-week-two-o3b-satellites-taken-out-of-service/>.

^{64/} ViaSat Inc., *FCC Int'l Bureau Presentation* (Apr. 13, 2011), available at http://licensing.fcc.gov/myibfs/download.do?attachment_key=910374 (“ViaSat Presentation”).

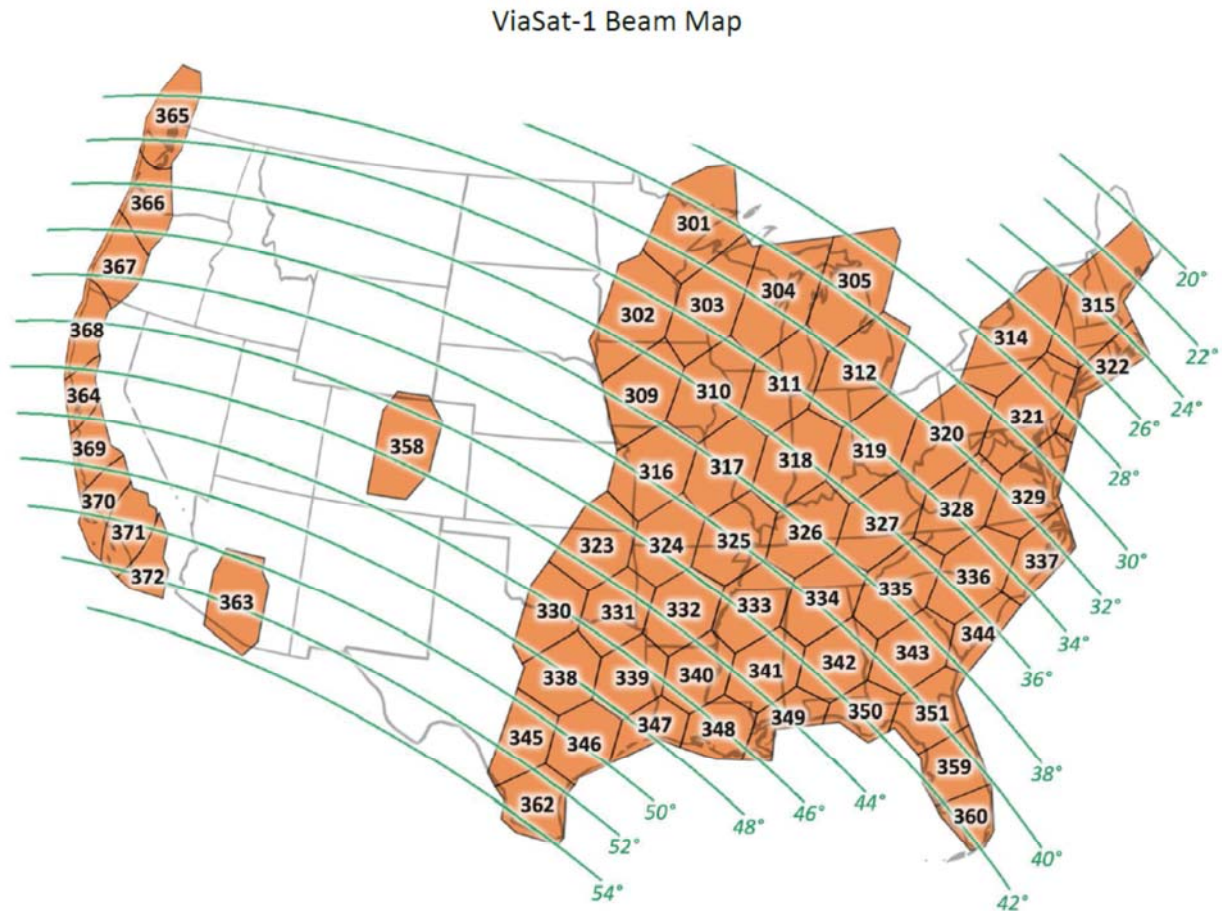


Figure 3. *ViaSat-1 Spot Beams*^{65/}

Use of spectrum for satellite services meets many important needs. But the comparatively high cost of satellites (several hundred million dollars per satellite versus less than a hundred thousand dollars per cell site) and the very limited frequency reuse (a few tens of satellite spot beams versus a few hundred thousand cell towers) make it highly spectrally and economically inefficient in comparison with terrestrial cellular networks with respect to providing next generation mobile broadband to the general public. The Commission should focus this proceeding on how best to provide 5G *terrestrial* services using mmWave spectrum. FSS has already been authorized multiple gigahertz of spectrum, much of it solely for satellite

^{65/} See ViaSat, *Install Keys and Beam Maps* at 2 (updated May 21, 2015), https://www.viasat.com/sites/default/files/media/documents/2015_05_21_beam_map_with_keys_and_elevation-1.pdf (last visited Jan. 9, 2016).

use without the burden to share with terrestrial services. Moreover, some of the spectrum available for FSS use (e.g., the 40.0–42.0 GHz band and the 47.2–50.2 GHz band) has never been used. On the other hand, not a single hertz of mmWave spectrum has been allocated exclusively for mobile broadband. Without sufficient mmWave spectrum exclusively available for flexible terrestrial services that will not be compromised by satellite operations, mobile providers may not be willing to invest the significant capital that is needed to build nationwide coverage for 5G, thereby depriving the nation of a much better mobile broadband infrastructure than sub-6 GHz 4G systems can provide.

B. There Are Technological Problems and Limitations of FSS Operations in the Same Bands As Mobile Services, and Challenging Interference Coordination in the 39 GHz Band.

Practical and technological limitations make it exceedingly difficult for mobile and satellite services to operate in the same bands. The Commission has already recognized the difficulty of spectrum sharing between FSS space-to-earth and mobile operations, and this interference will exist at the 39 GHz band as well.^{66/} The Commission tentatively decided to preserve the satellite allocation in the 39 GHz band;^{67/} however, in light of the lack of current and anticipated use of the band for satellite operations and the impact that potential satellite use may have on mobile wireless terrestrial systems, it may wish to re-evaluate that determination. If the Commission continues to preserve the current satellite allocation in the hopes that demand for the band will develop in the future, then it must ensure that satellite technical regulations do not disrupt mobile wireless terrestrial use.

^{66/} See, e.g., *Service Rules for Advanced Wireless Services in the 2000-2020 MHz and 2180-2200 MHz Bands, et al.*, Report and Order and Order of Proposed Modification, 27 FCC Rcd. 16102, ¶ 163 (2012) (“[W]e believe that technological difficulties continue to make it impractical today for same band, separate mobile satellite and terrestrial operator sharing of this spectrum, and therefore propose to modify the existing MSS licenses so that satellite and terrestrial services are managed by the same operator.”).

^{67/} See *NPRM* at ¶ 45.

The Commission seeks comment on whether it would be reasonable to eliminate the prohibition against ubiquitous deployment of space-to-Earth user equipment in the 37.5–40 GHz band.^{68/} We strongly oppose this proposal. The limitation on FSS operations in the 37.5–40 GHz band is part of the Commission’s “soft segmentation” approach for the 37.5–42 GHz band.^{69/} Under that plan, the 37.5–40 GHz band is designated for use by terrestrial services while the 40–42 GHz band is designated for use by satellite services. Limiting FSS use of 37.5–40 GHz to gateway stations so that FSS terminals are not ubiquitously deployed in this band is an essential part of the regulatory structure to preserve the 37.5–40 GHz band for terrestrial services. Moreover, because 5G mobile broadband will significantly increase the utilization of this band for terrestrial operations, it is counterproductive to allow increased usage of the same band by satellite service that will cause challenging co-channel interference scenarios, potentially discouraging operators from investing and building 5G networks in this band.

Notwithstanding the market-based mechanisms the Commission proposed, interference from FSS to terrestrial mobile devices cannot be avoided. Even with the latest satellite technology, the size of the spot beams is enormous in comparison with mobile broadband cells. For example, ViaSat-1 uses 63 spot beams to cover 75% of the U.S., which means the average size of the spot beams is more than 115,000 square kilometers.^{70/} By way of comparison, the

^{68/} *Id.* at ¶ 160.

^{69/} See *Allocation and Designation of Spectrum for Fixed-Satellite Services in the 37.5-38.5 GHz, 40.5-41.5 GHz and 48.2-50.2 GHz Frequency Bands; Allocation of Spectrum to Upgrade Fixed and Mobile Allocations in the 40.5-42.5 GHz Frequency Band; Allocation of Spectrum in the 46.9-47.0 GHz Frequency Band for Wireless Services; and Allocation of Spectrum in the 37.0-38.0 GHz and 40.0-40.5 GHz for Government Operations*, Second Report and Order, 18 FCC Rcd. 25428 (2003).

^{70/} See *ViaSat Presentation*, *supra* note 64.

State of Virginia is approximately 110,000 square kilometers.^{71/} For O3b networks, each beam's footprint measures 700 kilometers in diameter.^{72/} The area covered by such a spot beam is therefore about 380,000 square kilometers, almost as large as the state of California (around 420,000 square kilometers).^{73/} Further, the potential interference does not end at the edge of the spot beam footprint. Rather, the potential area of interference caused by an FSS spot beam will likely be much bigger than the footprint of the spot beam.

Even if FSS operators could technically limit their spot beams, they likely would still elect to provide service in the same areas in which 5G terrestrial services would be provided. FSS operators themselves optimize their spot beams by pointing them to densely populated areas. For example, ViaSat-1 uses 63 spot beams to cover 75% of the U.S. (the east and west coast, Midwest, and the South), with much of the Great Plains and the Mountain States left uncovered (these areas are covered by older generation satellites instead).^{74/} Therefore, the idea of the 39 GHz band being used by 5G mobile services in urban and suburban area and shared by FSS in rural areas simply does not conform with the realities of FSS technology and business.

As ViaSat commented,^{75/} satellite broadband systems “will need continued access to ‘dedicated’ spectrum bands – a base of ‘core’ spectrum where they can operate on an unimpeded basis.” The satellite industry will therefore not benefit from the constrained use of the 39 GHz bands, while the potential concern of wide-area interference by satellite spot beams may discourage mobile operators from investing in 5G networks in these bands.

^{71/} *State Area Measurements and Internal Point Coordinates*, U.S. Census Bureau, available at <https://www.census.gov/geo/reference/state-area.html> (last visited Jan. 1, 2016) (“U.S. Census Bureau State Measurements”).

^{72/} *See O3b Technology Webpage*, *supra* note 62.

^{73/} *See U.S. Census Bureau State Measurements*, *supra* note 71.

^{74/} *See ViaSat Presentation*, *supra* note 64.

^{75/} Comments of ViaSat, Inc., GN Docket No. 14-177, RM-11664, at 5 (filed Jan. 15, 2015).

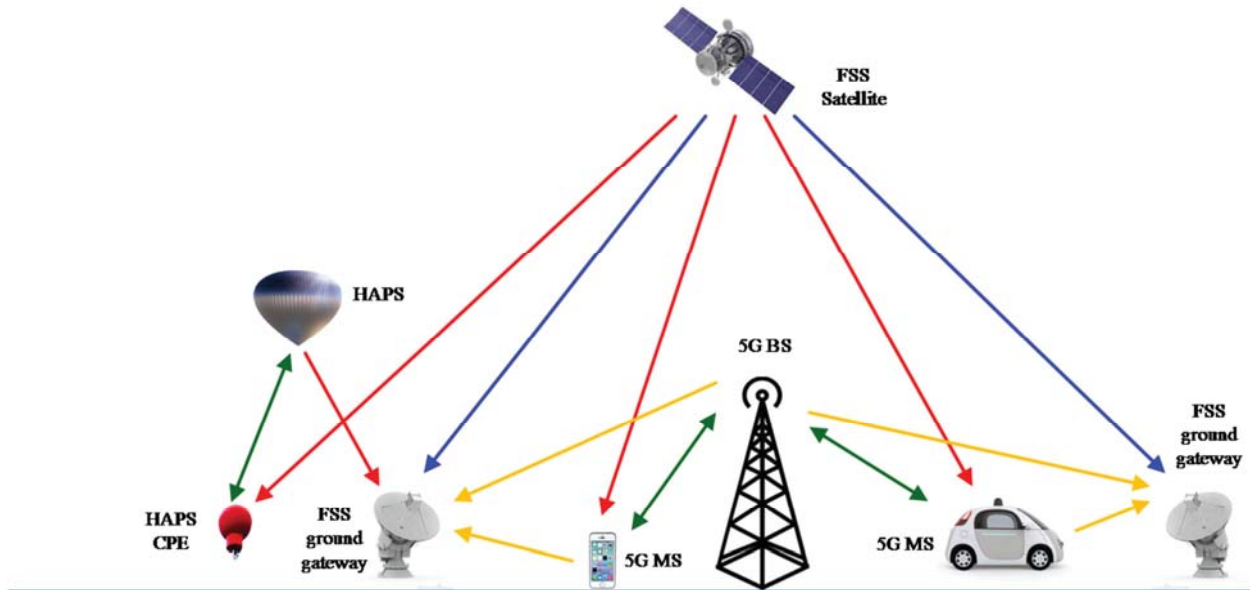


Figure 4. *Interference between mobile and satellite broadband services at 37 and 39 GHz bands*

As described more fully below, the two primary co-channel interference scenarios in the 39 GHz band are: (1) the interference from FSS satellites to terrestrial service stations; and (2) the interference from terrestrial service stations to FSS ground stations.

Interference from FSS satellites to terrestrial service stations. The current power flux density (“PFD”) limit of FSS in the 39 GHz band allows -117 dBW/m² per megahertz for angles of arrival between 25 and 90 degrees above the horizontal plane.^{76/} A PFD limit of -105 dBW/m² per megahertz is permitted when an FSS system raises power to compensate for rain-fade conditions at FSS earth stations,^{77/} although such conditions and the extent to which these limits can be exceeded will be subject of a further rulemaking.^{78/}

^{76/} 47 C.F.R. § 25.208(r)(1).

^{77/} 47 C.F.R. § 25.208(r)(2).

^{78/} See *Allocation and Designation of Spectrum for Fixed-Satellite Services in the 37.5-38.5 GHz, 40.5-41.5 GHz and 48.2-50.2 GHz Frequency Bands; Allocation of Spectrum to Upgrade Fixed and Mobile Allocations in the 40.5-42.5 GHz Frequency Band; Allocation of Spectrum in the 46.9-47.0 GHz Frequency Band for Wireless Services; and Allocation of Spectrum in the 37.0-38.0 GHz and 40.0-40.5 GHz for Government Operations*, Third Further Notice of Proposed Rulemaking, 25 FCC Rcd. 15663 (2010).

This rule is intended to allow FSS and fixed terrestrial services to coexist in the same spectrum and same geographic area. This may be possible when terrestrial fixed services use high gain antennas and communicate horizontally along the earth surface while FSS also uses high gain antennas and communicates vertically between the ground and the sky. However, as flexible services including mobile services are deployed at 39 GHz, the interference scenarios between FSS and terrestrial services in the same geographic area become much more complicated.

With -117 dBW/m^2 per megahertz PFD, the interference caused by a single satellite at an omnidirectional antenna with no gain at 39 GHz is: $I = S \cdot \frac{\lambda^2}{4\pi}$, which is about -140 dBm/MHz . When the possibility of multiple satellites is factored in, along with the fact that subscriber stations of terrestrial services may form beams upwards for the strongest paths from base stations (*e.g.*, a line-of-sight path from a base station up high, a diffraction path from the roof of a building or the crown of a tree, or a sky-to-earth link from a high altitude platform (“HAPS”) station), this value quickly becomes amplified. Our interference analysis^{79/} shows that the level of interference that terrestrial services will suffer from satellite services depends heavily on the skyward beamforming gain. This value is generally positive and can be significant for certain services. For example, we assume a moderate 6 dB skyward beamforming gain for 5G mobile stations as base stations tend to be deployed higher than mobile stations, and the mobile stations in general cannot form sharp beams to suppress interference from satellites. In this case, the coverage area of 5G service will be reduced by one percent due to interference from three satellites each with PFD of $-117 \text{ dBW/m}^2/\text{MHz}$. Although this number seems small, considering

^{79/} See Appendix B.

that U.S. mobile operators' capital expenditure ("CAPEX") reached \$34 billion in 2013^{80/} and will continue at this rate for years to come,^{81/} it is likely that U.S. mobile operators would need to spend billions more dollars to compensate for the one percent reduction in coverage area per cell.

For other services such as in-band backhaul for small cells, the skyward beamforming gain can be quite high because the high gain beams formed by small cells using large antenna arrays are generally pointed upward in order to communicate with the macro/micro base stations. These beams often have side lobes due to practical impairments such as phase and amplitude errors, coupling among antenna elements, and limited number of radiofrequency chains. For example, assuming a 10 dB skyward beamforming gain, the coverage area of in-band backhaul will be reduced by 2.7% due to three satellites. Other innovative services such as HAPS will likely have even higher skyward beamforming gain and will experience strong interference from satellites. For instance, assuming a 20 dB skyward beamforming gain, the coverage area of HAPS based terrestrial services will be reduced by 22% due to three satellites with PFD of -117 dBW/m²/MHz.

If the PFD limit of FSS is increased to -105 dBW/m²/MHz, with three satellites in the sky, our analysis shows that the coverage area reduction to 5G mobile services, in-band backhaul, and HAPS will be 15%, 30%, and 80%.^{82/} This will cause serious performance degradation to the terrestrial services, and it will likely force terrestrial service operators to plan their networks according to the worst-case scenario and suffer a significant increase in 5G rollout

^{80/} See Andrew Berg, *Report: U.S. Carriers Spent \$109 Per Citizen in CapEx in 2013*, WirelessWeek (June 9, 2014), available at <http://www.wirelessweek.com/news/2014/06/report-us-carriers-spent-109-citizen-capex-2013>.

^{81/} See Kavitha Majithia, *North American operator CAPEX to hit \$200B through 2020*, Mobile World Live (Oct. 27, 2015), available at <http://www.mobileworldlive.com/m360-2015-north-america/north-american-operator-capex-to-hit-200b-through-2020/>.

^{82/} See Appendix B, Table 6.

cost. Accordingly, we strongly recommend that the Commission not permit the PFD increase for FSS in the 37 GHz and 39 GHz bands, if the Commission decides to continue to allow FSS in this band. Retaining the PFD limit at -117 dBW/m²/MHz is particularly appropriate taking into account the fact that the 40–42 GHz band has been used little, if at all, more than 15 years after it has been allocated to FSS.^{83/} Should FSS operators—more than 15 years later—launch services in the 37.5–42 GHz band, then they should first utilize the 40–42 GHz band, which allows PFD up to -105 dBW/m²/MHz.

Interference from terrestrial stations to FSS ground stations in the 39 GHz band. With densely deployed terrestrial services (e.g., 5G mobile services), exclusion zones will be required for FSS ground stations to mitigate the interference from terrestrial stations. Take 5G mobile services as an example. Assume the exclusion zone radius is d , the 5G base station density outside of the exclusion zone is ρ_{BS} , and the 5G mobile station density outside of the exclusion zone is ρ_{MS} . For simplicity, we assume the path loss from the 5G base stations to the FSS ground station is: $\left(\frac{\lambda}{4\pi r}\right)^2 \cdot \frac{1}{r^\alpha}$, where α is the excess path loss exponent beyond free space propagation. We also assume the path loss from 5G mobile stations to the FSS ground station is: $\left(\frac{\lambda}{4\pi r}\right)^2 \cdot \frac{1}{r^\beta}$, where β is the excess path loss exponent beyond free space propagation. The interference from 5G base stations to the FSS ground station can be expressed as:

^{83/} See *Allocation and Designation of Spectrum for Fixed-Satellite Services in the 37.5-38.5 GHz, 40.5-41.5 GHz, and 48.2-50.2 GHz Frequency Bands; Allocation of Spectrum to Upgrade Fixed and Mobile Allocations in the 40.5-42.5 GHz Frequency Band; Allocation of Spectrum in the 46.0-47.0 GHz Frequency Band for Wireless Services; and Allocation of Spectrum in the 37.0-38.0 GHz and 40.0-40.5 GHz for Government Operations*, Report and Order, 13 FCC Rcd. 24649 (1998); see also *Allocation and Designation of Spectrum for Fixed-Satellite Services in the 37.5-38.5 GHz, 40.5-41.5 GHz, and 48.2-50.2 GHz Frequency Bands; Allocation of Spectrum to Upgrade Fixed and Mobile Allocations in the 40.5-42.5 GHz Frequency Band, Allocation of Spectrum in the 46.9-47.0 GHz Frequency Band for Wireless Services and Allocation of Spectrum in the 37.0-38.0 GHz and 40.0-40.5 GHz for Government Operations*, Notice of Proposed Rulemaking, 12 FCC Rcd. 10130 (1997).

$$\int_0^{2\pi} \int_d^{+\infty} \rho_{BS} \cdot \left(\frac{\lambda}{4\pi r}\right)^2 \cdot \frac{1}{r^\alpha} \cdot r dr d\theta = \frac{\rho_{BS} \lambda^2}{8\pi\alpha} \cdot d^{-\alpha}$$

Similarly, the interference from 5G mobile stations to the FSS ground station can be expressed as:

$$\int_0^{2\pi} \int_d^{+\infty} \rho_{MS} \cdot \left(\frac{\lambda}{4\pi r}\right)^2 \cdot \frac{1}{r^\beta} \cdot r dr d\theta = \frac{\rho_{MS} \lambda^2}{8\pi\beta} \cdot d^{-\beta}$$

The impact of this interference is shown in Appendix B.^{84/} The interference is highly sensitive to the assumed excess path loss exponent beyond free space propagation. For example, assuming $\alpha = \beta = 0.5$, an exclusion zone with 2 kilometer radius will be needed to avoid more than 1 dB degradation due to interference from 5G base stations and mobile stations. However, a slight decrease of α and β to $\alpha = \beta = 0.4$ would mean an exclusion zone with 20 kilometer radius would be required to avoid more than 1 dB degradation. The actual value of α and β —how fast the 5G mobile services signals decay beyond free space propagation—will be dependent, however, on the environment and deployment. This creates challenges in the coordination between FSS operators and mobile operators should FSS operators decide to purchase licenses for exclusion zone purposes.

C. Operation of FSS Gateway Earth Stations in the 28 GHz Band Does Not Present the Same Interference Risks.

Straight Path does not oppose the upgrade of FSS gateway earth stations to co-primary status in the 28 GHz band using the mechanisms the Commission suggests.^{85/} While space-to-earth transmissions from FSS systems are problematic for terrestrial 5G deployment for the reasons noted above, earth-to-space transmissions are not. If FSS operators wish to secure

^{84/} See Appendix B, Table 7.

^{85/} See *NPRM* at ¶ 129.

primary status in the 28 GHz band they may participate in an auction for any vacant spectrum and operate earth stations within the geographic area covered by their authorization. The Commission asks whether FSS operators should be able to convert their authorizations to primary status *before* the Commission conducts an auction for vacant spectrum.^{86/} Straight Path disagrees. Allowing FSS licensees an advance opportunity to prevent use of the spectrum for terrestrial purposes is not in the public interest. If FSS operators wish to have that opportunity, then they should compete against others who also value the spectrum.

V. LICENSING, OPERATIONS, AND PERFORMANCE RULES

Treatment of Incumbent Licenses. The Commission recognizes that existing LMDS and 39 GHz licensees may be planning to meet current substantial service and renewal expectancy requirements, and proposes to apply the existing performance requirement to incumbent licensees at the end of their current license terms (if the term expires prior to March 1, 2021).^{87/} Nevertheless, the Commission asks whether existing licensees should be permitted to meet the current performance requirement earlier.^{88/} Straight Path agrees with the Commission's alternative proposal. Specifically, it recommends that the FCC permit licensees to make substantial service demonstrations to satisfy current requirements *prior* to the end of a license term. If a licensee elects to make an early substantial service showing, then its subsequent license term should include the remainder of the original license term *plus* the additional ten year renewal term. This process would facilitate rapid deployment of 5G services because licensees would not be required to artificially focus on a fixed services substantial service demonstration at the end of a license term for the purpose of obtaining a renewal expectancy. Instead, licensees

^{86/} See *id.* at ¶ 140.

^{87/} *Id.* at ¶ 219.

^{88/} *Id.*

could proactively make the required performance showing sooner rather than later and begin construction and deployment of 5G mobile systems as soon as possible.

Security Requirements. In the *NPRM*, the Commission seeks comment on “how to ensure that effective security features are built into key design principles for all mmW band communications devices and networks,” and it poses questions about “three critical security components”—confidentiality, integrity, and availability.^{89/} Straight Path opposes the imposition of any such security requirements. While Straight Path appreciates and shares the Commission’s concern for security, imposition of these obligations is inconsistent with Commission practice and contrary to the public interest.

The Commission has repeatedly determined not to impose technical standards on commercial services.^{90/} Given the rapid evolution of technology, the adoption of standardized security or architectural methods could potentially freeze current technology in place and limit flexible network management. Straight Path therefore opposes the imposition of technical standards, which are inconsistent with the Commission’s goals of promoting flexible use of the mmWave bands and innovation of next-generation wireless broadband technologies.

^{89/} See *id.* at ¶¶ 260–265.

^{90/} See, e.g., *Amendment of the Commission’s Rules with Regard to Commercial Operations in the 1695-1710 MHz, 1755-1780 MHz, and 2155-2180 MHz Bands*, Report and Order, 29 FCC Rcd. 4610, ¶¶ 104–105 (2014) (declining to impose an LTE interface standard in the AWS-3 spectrum because mandating a particular technology would “hamstring innovation and development and be contrary to the Commission’s policy to preserve technical flexibility and refrain from imposing unnecessary technical standards”) (quoting Reply Comments of T-Mobile USA, Inc., GN Docket No. 13-185, at 20–21 (filed Oct. 28, 2013)); *Implementation of Section 6002(b) of the Omnibus Budget Reconciliation Act of 1993 Annual Report and Analysis of Competitive Market Conditions With Respect to Mobile Wireless, Including Commercial Mobile Services*, Sixteenth Report, 28 FCC Rcd. 3700, ¶ 102 (2013) (stating “the Commission has adopted a general policy of providing licensees with significant flexibility to decide which services to offer and what technologies to deploy on spectrum used for the provision of mobile wireless services”); *Expanding Access to Broadband and Encouraging Innovation Through Establishment of an Air-Ground Mobile Broadband Secondary Service for Passengers Aboard Aircraft in the 14.0-14.5 GHz Band*, Notice of Proposed Rulemaking, 28 FCC Rcd. 6765, ¶ 101 (2013) (the FCC “strive[s] to establish technology neutral rules that allow for competing technologies and changes in technology over time without the need to change our rules”).

VI. TECHNICAL RULES

Straight Path applauds the Commission for taking a “nimble and flexible”^{91/} approach to the proposed technical rules for the mmWave bands and provides the following feedback on the issues presented in the *NPRM*.

A. Flexible Duplexing Rules

While Straight Path supports the Commission’s finding to allow both TDD and FDD deployment in the 28 GHz, 39 GHz, and 37 GHz bands,^{92/} it also agrees with many other commenters that TDD will be the preferred mode of operation in the mmWave bands for mobile services.^{93/} As noted in Section III.D, above, the Commission should assume TDD will be the predominant technology used in these bands.

B. Transmission Power Limits and Antenna Height

Base Stations. The Commission seeks comment on whether a higher transmission power limit should be considered for the in-band application where the same equipment is used for mobile service and backhaul service.^{94/} Straight Path recommends that the Commission retain the same Effective Isotropic Radiated Power (“EIRP”) limit for mobile services and in-band backhaul services that use the same equipment because these services have similar output power and beam width as the mobile services. For backhaul services using high-gain dish antennas (e.g., 40–50 dB), the maximum EIRP limit for fixed services (e.g., 85 dBm) should apply.

^{91/} See *NPRM* at ¶ 266.

^{92/} See *id.* at ¶ 269.

^{93/} See, e.g., Comments of Qualcomm Inc., GN Docket No. 14-177, RM-11664, at 12–13 (filed Jan. 15, 2015); Comments of Motorola Mobility LLC, GN Docket No. 14-177, *et al.*, at 7 (filed Jan. 15, 2015); Reply Comments of Nokia Solutions and Networks US, LLC, GN Docket No. 14-177, at 6 (filed Feb. 17, 2015).

^{94/} *NPRM* at ¶ 276.

Mobile Stations. We are pleased that the Commission proposes rules based on Straight Path’s recommendation that, for mobile stations, the same limit of 43 dBm maximum EIRP that is already allowed in the 57–64 GHz band under the current Part 15 rules should apply for the remainder of the mmWave bands.^{95/} As the Commission recognized, “the combined effect of [its radiofrequency exposure rules] and a maximum peak EIRP limit of 43 dBm would be to ensure compliance with exposure limits while allowing industry flexibility to develop higher-powered transmitters for situations where an appropriate separation distance is maintained” between the device and the user’s body.^{96/}

A 43 dBm maximum EIRP limit is more appropriate than one based on output power. The difference between output power and EIRP for mobile stations operating in the bands below 3 GHz is practically small, partially because the large wavelength of these frequencies limits the amount of antenna gain achievable in the form factor of a mobile or portable device. A considerable amount of antenna gain can be achieved, however, in mobile or portable devices operating in mmWave bands that can fit comfortably multiple antenna arrays with 4 to 16 antenna elements in each array. The transmissions from these devices is generally highly directional (with directivity around 10 dB or more). The maximum EIRP of 43 dBm means the average output power of these devices will be less than 33 dBm (or 2 watts) even if they operate at the peak EIRP all the time. This level of output power is in line with the mobile station power limit for Cellular Radiotelephone Service,^{97/} Broadband PCS,^{98/} WCS,^{99/} AWS,^{100/} the 700 MHz

^{95/} See *id.* at ¶ 279.

^{96/} *Id.*

^{97/} For the Cellular Radio Telephone Service, the maximum effective radiated power (“ERP”) of mobile transmitters is 7 watts (equivalent to 11.5 Watts or 40.6 dBm EIRP). See 47 C.F.R. § 22.913(a)(2).

^{98/} For Broadband PCS, the maximum EIRP of mobile stations is 2 watts. See 47 C.F.R. § 24.232(c).

band,^{101/} Wi-Fi,^{102/} and the 60 GHz band.^{103/} Conversely, if the EIRP of mmWave mobile devices is required to be at the same level as the output power limit for the sub-3GHz cellular services, i.e., 33 dBm or so, the output power of the mmWave mobile devices would be about 10 dB lower than the output power of mobile devices operating in sub-3 GHz bands. This would unnecessarily limit mmWave 5G cells to similar range as Wi-Fi hot spots, restrict mmWave 5G to a hot spot and small cell technology, discourage operators from investing in a nationwide upgrade into a Gbps mobile broadband infrastructure, and eliminate much of the economic value of 5G and the 28 GHz, 37 GHz, and 39 GHz bands.

In addition, as our interference analysis shows,^{104/} the interference from 5G mobile services to FSS gateway stations is dominated by interference generated by 5G base stations. There is little benefit to FSS to further lower the transmission power of 5G mobile stations.

Antenna Height. The Commission notes that its PCS and AWS rules require reduction of transmission power limit when the antenna height is more than 1,000 feet, and it seeks comment on whether a similar antenna height should be applied to base stations operating in the proposed

^{99/} For the WCS A or B blocks, the average EIRP of mobile stations must not exceed 250 milliwatts within any 5 megahertz of authorized bandwidth and must not exceed 50 milliwatts within any 1 megahertz of authorized bandwidth. 47 C.F.R. § 27.50(a)(3)(i).

^{100/} For the AWS band, the maximum EIRP of mobile stations is 1 watt. *See* 47 C.F.R. § 27.50(d)(4).

^{101/} For the 700 MHz band, the maximum ERP of control and mobile stations is 30 watts (equivalent to 50 watts or 47 dBm EIRP), while the maximum ERP of portable stations (hand-held devices) is 3 watts (equivalent to 5 watts or 37 dBm EIRP). *See* 47 C.F.R. § 27.50(b)(9)–(10), (c)(9)–(10).

^{102/} For 2.4 GHz and 5 GHz unlicensed transmissions (e.g., Wi-Fi 11 a/b/g/n), the maximum output power is 1 watt for antennas with directional gain less than 6 dBi. *See* 47 C.F.R. § 15.247(b). In the 2.4 GHz band, an even higher EIRP is allowed with total conducted output power reduced by 1 dB for each 3 dB that the directional gain of the antenna/antenna array exceeds 6 dBi. *See* 47 C.F.R. § 15.247(c)(2)(ii).

^{103/} For 60 GHz unlicensed transmissions (e.g., Wi-Fi 11ad), the maximum average EIRP is 40 dBm with maximum peak EIRP of 43 dBm. *See* 47 C.F.R. § 15.255(b).

^{104/} *See* Appendix B, Table 7.

bands.^{105/} Straight Path believes that the 1,000 foot height limit will be sufficient to mitigate the risk of harmful interference from high-elevation transmitters in the mmWave bands.

C. Limits on Terrestrial Emissions.

The Commission seeks comment on whether a radiated emission limit of -13 dBm/MHz can be supported by 5G transmitters operating in the licensed mmWave bands, and if so, the resolution bandwidth and frequency offset that should be considered to define out-of-band emissions (“OOBE”) and spurious emissions.^{106/} Straight Path believes that a radiated emission limit of -13 dBm/MHz is achievable and adequate. Even for a base station with maximum EIRP of 62 dBm per 100 MHz (42 dBm/MHz), it will only take 55 dB of attenuation to decrease to -13 dBm/MHz, which we believe is achievable with a combination of digital filtering and waveform shaping, guard bands, and RF filtering. The RF filtering can be achieved by distributed element filters on printed circuit boards. The transceiver elements including the power amplifier and the antenna are in themselves frequency selective and thus contribute to suppressing the out-of-band emissions. However, the Commission should not unnecessarily tighten the emission mask to a level that manufacturers find it difficult to achieve. As Straight Path has previously suggested,^{107/} the Commission should define the OOBE in reference to the average EIRP across the entire authorized bandwidth along the spatial direction with the strongest average EIRP.

We expect that the -13 dBm/MHz OOBE under consideration in the *NPRM* will be well tolerated in real operations. Transmissions from both base station and mobile stations will be highly directional (greater than 20 dB directivity at base station, greater than 10 dB directivity at

^{105/} See *NPRM* at ¶ 277.

^{106/} *Id.* at ¶ 286.

^{107/} See Letter from Jerry Pi, Chief Technology Officer, Straight Path Communications Inc. to Marlene H. Dortch, Secretary, FCC, GN Docket No. 14-177 (filed Aug. 5, 2015).

mobile station). The OOB E that is defined along the strongest spatial direction will already result in much lower overall OOB E averaged across all spatial directions. The thermal noise floor will be approximately -110 dBm/MHz, including the noise figure of a typical receiver. Assuming the interference is 6 dB below the thermal noise floor, which results in 1 dB desensitization, an additional 103 dB attenuation is required. If the downlink and uplink time slots are synchronized between adjacent channels, then the adjacent channel interference scenarios are simplified into base station to mobile station (“BS→MS”) and mobile station to base station (“MS→BS”) because the interference scenarios of BS→BS and MS→MS are eliminated due to synchronization. These interference scenarios are typically transient and can be effectively mitigated due to planning in deployment in adjacent channels. If TDD systems are deployed asynchronously in adjacent channels, however, then uplink-downlink interference can occur, which complicates the interference scenarios. In this case, the BS→BS interference scenario would require careful site coordination between adjacent channel deployments, while the MS→MS interference scenario has no effective solution. The issue of interference between asynchronous TDD systems in adjacent channels is no different from other TDD bands, including sub-3 GHz TDD bands. Therefore, if the mobile station density is high, TDD synchronization between adjacent channels is highly recommended.

D. Equipment Authorization.

RF Exposure Compliance. Existing rules govern RF protection in the 28 GHz and 39 GHz bands—the Maximum Permissible Exposure (“MPE”) limit is 1 mW/cm² averaged over 30 minutes for base stations.^{108/} The MPE limit is 1 mW/cm² without time averaging for mobile and

^{108/} See 47 C.F.R. § 1.1310.

portable devices.^{109/} These MPE limits are in line with the recommended guidelines by the International Commission on Non-Ionizing Radiation Protection (ICNIRP).^{110/} These are well established guidelines in the industry. In addition, Qualcomm has suggested that spatial and time averaging may be needed to define meaningful exposure and assess the heating effect (temperature rise) in tissue.^{111/} We support this proposal. We recommend that the Commission continue to following the ICNIRP Guidelines, including the spatial area and time period for averaging the power densities.^{112/}

Moreover, should the Commission desire to further study the RF exposure limits for these bands, it should do so as part of the ongoing proceeding on RF exposure limits and policies.^{113/} Since clear and well established rules and guidelines already exist for RF exposure in these bands, the progress of this proceeding should not be encumbered by the Commission's continuing evaluation of this subject. Rather, new rules for these bands, if any, can be implemented when that proceeding is completed.

VII. CONCLUSION

Straight Path appreciates the Commission's efforts to develop a regulatory framework that promotes innovation and investment in 5G mobile technologies and services in the mmWave bands. It urges the Commission to quickly adopt rules in order to provide the flexibility and

^{109/} See 47 C.F.R. §§ 2.1091; 2.1093.

^{110/} See *ICNIRP Guidelines for Limiting Exposure to Time-Varying Electric, Magnetic and Electromagnetic Fields (up to 300 GHz)*, Int'l Comm'n on Non-Ionizing Radiation Protection (1998), available at <http://www.icnirp.org/cms/upload/publications/ICNIRPemfgdl.pdf> ("ICNIRP Guidelines").

^{111/} See Letter from John W. Kuzin, Senior Director & Regulatory Counsel, Qualcomm Inc. to Marlene H. Dortch, Secretary, FCC, GN Docket No. 14-177, *et al.* (filed Dec. 18, 2015).

^{112/} See *ICNIRP Guidelines*, *supra* note 110, at Table 5.

^{113/} See *Reassessment of Federal Communications Commission Radiofrequency Exposure Limits and Policies*, First Report and Order, Further Notice of Proposed Rule Making and Notice of Inquiry, 28 FCC Rcd. 3498 (2013).

regulatory certainty needed to facilitate expeditious deployment of 5G operations. The regulatory scheme should maximize the key value of mmWave technology as a wide-area service capable of delivering mobile broadband service. Straight Path looks forward to working with the Commission to create a successful regulatory environment for next-generation wireless services, and to ensure the effective deployment of 5G mobile broadband.

Respectfully submitted,

/s/ Davidi Jonas

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Appendix A

Link Budget Analysis of 5G Systems at 39 GHz in New York City, University of Texas Campus, and Rural Areas

Table 3. 39 GHz 5G System Link Budget (New York City)^{114/}

5G mobile service link budget	Downlink O2O	Uplink O2O	Downlink O2I	Uplink O2I
PA output power (dBm)	20	15	20	15
Number of PAs	64	16	64	16
Total output power (dBm)	38	30	38	30
Number of Tx antenna element	256	16	256	16
Tx antenna element gain (dB)	6	6	6	6
Antenna & feed network loss (dB)	3	2	3	2
Total Tx antenna array gain (dB)	27	16	27	16
EIRP (dBm)	65.14	43.08	65.14	43.08
Inter-Site Distance (m)	500	500	150	150
Path loss = $64.3 + 34\log_{10}(d) + 6d/1000$ (dB)	149.69	149.69	130.70	130.70
Additional Loss (Penetration, blocking, etc.)	10.00	10.00	30.00	30.00
Received power (dBm)	-94.54	-116.60	-95.55	-117.61
Bandwidth (MHz)	500	500	500	500
Thermal noise (dBm)	-87.01	-87.01	-87.01	-87.01
Noise Figure (dB)	5.00	5.00	5.00	5.00
SNR (dB) per Rx antenna element	-12.53	-34.59	-13.54	-35.60
Number of Rx antenna element	16	256	16	256
Rx antenna element gain (dB)	6	6	6	6
Rx antenna feed network loss (dB)	2	3	2	3
Total Rx antenna array gain (dB)	16	27	16	27
SNR after beamforming (dB)	3.51	-7.51	2.50	-8.52
Implementation loss (dB)	3.00	3.00	3.00	3.00
Number of MIMO streams	1	1	1	1
Spectral efficiency (bit/channel use)	1.09	0.12	0.92	0.10
System overhead	40%	40%	40%	40%
Duty cycle	62.50%	37.50%	62.50%	37.50%
Throughput (Mbps)	203.84	13.82	172.38	11.05

^{114/} 160 dB link budget assumed. “O2O” stands for “outdoor-to-outdoor”. “O2I” stands for “outdoor-to-indoor”. Additional loss of 10 dB and 30 dB are assumed for O2O and O2I cases, respectively.

Table 4. 39 GHz 5G System Link Budget (University of Texas at Austin Campus)^{115/}

5G mobile service link budget	Downlink O2O	Uplink O2O	Downlink O2I	Uplink O2I
PA output power (dBm)	20	15	20	15
Number of PAs	64	16	64	16
Total output power (dBm)	38	30	38	30
Number of Tx antenna element	256	16	256	16
Tx antenna element gain (dB)	6	6	6	6
Antenna & feed network loss (dB)	3	2	3	2
Total Tx antenna array gain (dB)	27	16	27	16
EIRP (dBm)	65.14	43.08	65.14	43.08
Inter-Site Distance (m)	3100	3100	900	900
Path loss = $64.3 + 23\log_{10}(d) + 6d/1000$ (dB)	149.85	149.85	129.88	129.88
Additional loss (penetration, blocking, etc.)	10.00	10.00	30.00	30.00
Received power (dBm)	-94.71	-116.77	-94.73	-116.80
Bandwidth (MHz)	500	500	500	500
Thermal noise (dBm)	-87.01	-87.01	-87.01	-87.01
Noise Figure (dB)	5.00	5.00	5.00	5.00
SNR (dB) per Rx antenna element	-12.70	-34.76	-12.72	-34.79
Number of Rx antenna element	16	256	16	256
Rx antenna element gain (dB)	6	6	6	6
Rx antenna feed network loss (dB)	2	3	2	3
Total Rx antenna array gain (dB)	16	27	16	27
SNR after beamforming (dB)	3.34	-7.68	3.32	-7.70
Implementation loss (dB)	3.00	3.00	3.00	3.00
Number of MIMO streams	1	1	1	1
Spectral efficiency (bit/channel use)	1.06	0.12	1.05	0.12
System overhead	40%	40%	40%	40%
Duty cycle	62.50%	37.50%	62.50%	37.50%
Throughput (Mbps)	198.38	13.32	197.56	13.25

^{115/} 160 dB link budget assumed. “O2O” stands for “outdoor-to-outdoor”. “O2I” stands for “outdoor-to-indoor”. Additional loss of 10 dB and 30 dB are assumed for O2O and O2I cases, respectively.

Table 5. 39 GHz 5G System Link Budget (Rural Areas)^{116/}

5G mobile service link budget	Downlink O2O	Uplink O2O	Downlink O2I	Uplink O2I
PA output power (dBm)	20	15	20	15
Number of PAs	64	16	64	16
Total output power (dBm)	38	30	38	30
Number of Tx antenna element	256	16	256	16
Tx antenna element gain (dB)	6	6	6	6
Antenna & feed network loss (dB)	3	2	3	2
Total Tx antenna array gain (dB)	27	16	27	16
EIRP (dBm)	65.14	43.08	65.14	43.08
Inter-Site Distance (m)	4800	4800	1700	1700
Path loss = $64.3 + 20\log_{10}(d) + 6d/1000$ (dB)	149.78	149.78	130.03	130.03
Additional loss (penetration, blocking, etc.)	10.00	10.00	30.00	30.00
Received power (dBm)	-94.64	-116.70	-94.88	-116.94
Bandwidth (MHz)	500	500	500	500
Thermal noise (dBm)	-87.01	-87.01	-87.01	-87.01
Noise Figure (dB)	5.00	5.00	5.00	5.00
SNR (dB) per Rx antenna element	-12.63	-34.69	-12.87	-34.93
Number of Rx antenna element	16	256	16	256
Rx antenna element gain (dB)	6	6	6	6
Rx antenna feed network loss (dB)	2	3	2	3
Total Rx antenna array gain (dB)	16	27	16	27
SNR after beamforming (dB)	3.41	-7.61	3.17	-7.85
Implementation loss (dB)	3.00	3.00	3.00	3.00
Number of MIMO streams	1	1	1	1
Spectral efficiency (bit/channel use)	1.07	0.12	1.03	0.11
System overhead	40%	40%	40%	40%
Duty cycle	62.50%	37.50%	62.50%	37.50%
Throughput (Mbps)	200.71	13.54	192.81	12.82

^{116/} 160 dB link budget assumed. “O2O” stands for “outdoor-to-outdoor”. “O2I” stands for “outdoor-to-indoor”. Additional loss of 10 dB and 30 dB are assumed for O2O and O2I cases, respectively.

Appendix B

Interference Analysis for Overlaying Terrestrial Flexible Services and FSS

Table 6. FSS Interference to 5G terrestrial services in the 39 GHz band

Impact to 5G due to satellite interference	Access	Backhaul	HAPS	Access	Backhaul	HAPS
PFD limit (dBm/m²/MHz)	-87	-87	-87	-75	-75	-75
Number of satellites in view	3	3	3	3	3	3
Frequency (GHz)	39.00	39.00	39.00	39.00	39.00	39.00
Wavelength (meter)	0.00769	0.00769	0.00769	0.00769	0.00769	0.00769
Interference on omni directional antenna (dBm/MHz)	-135.50	-135.50	-135.50	-123.50	-123.50	-123.50
Upward beamforming gain (dB)	6.00	10.00	20.00	6.00	10.00	20.00
Interference after beamforming (dBm/MHz)	-129.50	-125.50	-115.50	-117.50	-113.50	-103.50
Thermal noise (dBm/MHz)	-114.00	-114.00	-114.00	-114.00	-114.00	-114.00
Noise figure (dB)	4.00	4.00	4.00	4.00	4.00	4.00
Effective thermal noise (dBm/MHz)	-110.00	-110.00	-110.00	-110.00	-110.00	-110.00
Total interference + thermal noise (dBm/MHz)	-109.95	-109.88	-108.92	-109.29	-108.40	-102.62
Rise over thermal due to satellite interference (dB)	0.05	0.12	1.08	0.71	1.60	7.38
Coverage reduction due to satellite interference	1.11%	2.74%	21.99%	15.10%	30.88%	81.71%

Table 7. Interference from 5G terrestrial services to FSS ground stations

Impact from 5G to satellite ground stations			
Frequency (GHz)	39	39	39
Wavelength (meter)	0.00769	0.00769	0.00769
5G base station output power (dBm/MHz)	13	13	13
5G mobile station output power (dBm/MHz)	0	0	0
Exclusion zone (km)	20.00	2.00	0.10
5G base station density (per km ²)	2	2	2
5G downlink transmission duty cycle	30%	30%	30%
Excess path loss exponent for interference from base station	0.40	0.50	0.75
5G mobile station density (per km ²)	100	100	100
5G uplink transmission duty cycle	10%	10%	10%
Excess path loss exponent for interference from mobile station	0.40	0.50	0.75
Interference due to 5G base stations (dBm/MHz)	-118.72	-118.99	-119.25
Interference due to 5G mobile stations (dBm/MHz)	-119.51	-119.78	-120.03
Thermal noise (dBm / MHz)	-114.00	-114.00	-114.00
Noise figure (dB)	4.00	4.00	4.00
Effective thermal noise (dBm / MHz)	-110.00	-110.00	-110.00
Total interference + thermal noise (dBm/MHz)	-109.04	-109.10	-109.14
Rise over thermal due to 5G (dB)	0.96	0.90	0.86